Distribution and Abundance of Herring and other Pelagic Fish off the West Coast of Vancouver Island in September, November, 1980, and March, 1981, and in the Strait of Georgia in November, 1980

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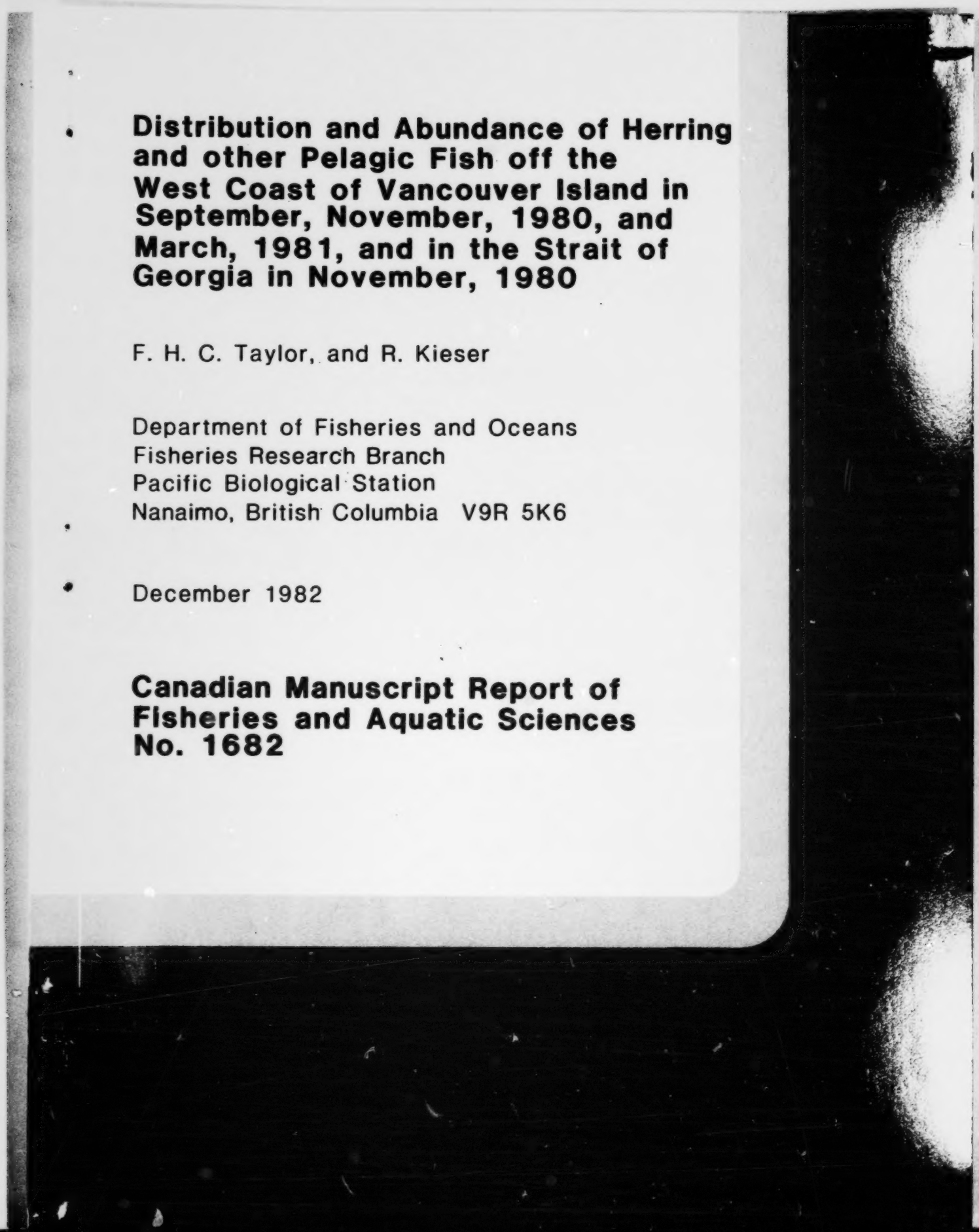

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December 1982

DISTRIBUTION AND ABUNDANCE OF HERRING AND OTHER PELAGIC FISH OFF THE WEST COAST OF VANCOUVER ISLAND IN SEPTEMBER, NOVEMBER, 1980, AND MARCH, 1981, AND IN THE STRAIT OF GEORGIA IN NOVEMBER, 1980

by

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ABSTRACT

Taylor, F. H. C., and R. Kieser. 1982. Distribution and abundance of herring and other pelagic fish off the west coast of Vancouver Island in September, November, 1980, and March, 1981, and in the Strait of Georgia in November, 1980. Can. MS Rep. Fish. Aquat. Sci. 1682: vi + 167 p.

Hydroacoustic cruises were carried out in September, November, 1980, and March, 1981, to determine the distribution and abundance of herring off the west coast of Vancouver Island. There were additional surveys in November in the Strait of Georgia to assess that spawning stock (which summers off the west coast), and in March in Barkley and Clayoquot Sounds to determine the abundance of west coast spawners. The timing of the cruises in relation to migration proved critical and was not satisfactorily attained.

In September, 67,740 t of herring were found off the west coast, in November 53,700 t, and in March 33,465 t. In September an additional 10,480 t were located off Victoria.

In all months most of the herring occurred south of Amphitrite Point, mainly along the outer edge of the shelf. In September almost half was south of the U.S./Canadian fishing boundary; however, the quantity in this area decreased sharply in November. Smaller concentrations occurred on La Perouse and Swiftsure Banks in September and November but in March the largest concentration was found in the latter area. Faulty equipment negated the results of the November Strait of Georgia survey. The surveys of Barkley and Clayoquot Sounds unfortunately occurred mainly after spawning, when most of the herring had left.

In September 67,230 t of hake and 31,880 t of pollock were found in a broad band from Cape Beale Spit to the Juan de Fuca Trench. In November the quantity of hake had decreased to 33,870 t, presumably due to migration south. The quantity of pollock was essentially unchanged. In March, no hake were identified offshore although small amounts were found in the inlets.

Dogfish increased from 10,120 t in September to 33,455 t in November and 38,590 t in March. In September the dogfish were mainly on the outer edge of the shelf, but by March were concentrated along the inner edge of the Prairie Grounds. Yellowtail and redstripe rockfish occurred in small quantities in September and November. The March estimates of rockfish are unreliable.

Key words: Hydroacoustic, echointegration, biomass, distribution, Pacific herring, hake, pollock, dogfish, rockfish.

RÉSUMÉ

Taylor, F. H. C., and R. Kieser. 1982. Distribution and abundance of herring and other pelagic fish off the west coast of Vancouver Island in September, November, 1980, and March, 1981, and in the Strait of Georgia in November, 1980. Can. MS Rep. Fish. Aquat. Sci. 1682: vi + 167 p.

Des levés hydroacoustiques ont été menés en septembre et novembre 1980 et en mars 1981 afin de déterminer la répartition et l'abondance du hareng au large de la côte ouest de l'île Vancouver. D'autres levés ont été effectués en novembre dans le détroit de Géorgie dans le but d'évaluer le stock reproducteur (qui passe l'été au large de la côte ouest) et en mars dans les baies Barkley et Clayoquot pour dénombrer les géniteurs de la côte ouest. La synchronisation des expéditions avec la migration s'est révélée un facteur important et n'a pas été réalisée de façon satisfaisante.

En septembre, novembre et mars, 67 740 t, 53 700 t et 33 465 t respectivement ont été localisées au large de la côte ouest. Egalement en septembre, 10 480 t ont été trouvées au large de Victoria.

Pendant tous les mois, la plus grande partie du hareng était présente au sud de la pointe Amphitrite, surtout le long du bord extérieur de la plate-forme. En septembre, presque la moitié se trouvait au sud de la limite de pêche canado-américaine. Toutefois, cette quantité a brusquement diminué en novembre. De plus petites concentrations étaient présentes dans la région des bancs La Pérouse et Swiftsure en septembre et novembre, mais en mars la plus grande concentration se trouvait dans ce dernier secteur. De l'équipement défectueux a réduit à rien les résultats du levé dans le détroit de Géorgie en novembre. Les levés dans les baies Barkley et Clayoquot ont malheureusement été effectués surtout après la fraie, au moment où la plupart des harengs avaient quitté les lieux.

En septembre, 67 230 t de merlu et 31 880 t de goberge ont été localisées en une vaste bande du cap Beale Spit à la tranchée Juan de Fuca. La quantité de merlu avait diminué à 33 870 t en novembre, probablement par suite de la migration vers le sud. La quantité de goberge n'avait presque pas varié. En mars, aucun merlu n'a été localisé en haute mer quoique de petites quantités étaient présentes dans les inlets.

La quantité d'aiguillats est passée de 10 120 t en septembre à 33 455 t en novembre et à 38 590 t en mars. En septembre, ils étaient présents surtout au rebord extérieur de la plate-forme, mais en mars ils s'étaient concentrés le long du rebord intérieur des Prairies Grounds. Les sébastes à queue jaune et les sébastes à raie rouge étaient présents en petites quantités en septembre et novembre. Les évaluations de la quantité de sébastes en mars sont douteuses.

Mots-clés: hydroacoustique, intégration des sondages acoustiques, biomasse, répartition, hareng du Pacifique, goberage, aiguillat, sébaste.

I. INTRODUCTION

One requirement for the effective management of a fishery is an estimate of the size of the stock at some period before the fishery. In general, the usefulness of the estimate to managers will depend on the accuracy of the estimate and the length of lead-time with which it can be provided. To provide herring managers with population estimates with a longer lead-time than previously available, the possibility was examined of making acceptably accurate acoustic estimates of the size of herring populations while the stocks were feeding offshore, before the start of the inshore spawning migrations.

Offshore surveys would have four objectives:

1. to determine whether or not echointegration surveys can provide information on herring stock size pertinent to management, and then

2. to estimate the biomass of herring offshore and to determine their distribution at a time most suited for management purposes.

3. to determine the distribution, and to estimate the biomass of recruits to provide a basis from which to predict stock size at least a year in advance.

4. to tag adult herring offshore to identify the spawning populations to which the offshore stocks contribute.

There are three major offshore regions where herring are known to occur in summer, off the west coast of Vancouver Island, in Queen Charlotte Sound, and in Hecate Strait. The first area was considered the most important as it has long been considered to cover the feeding grounds of the Strait of Georgia and west coast of Vancouver Island spawning populations, the major southern B.C. stocks. The inshore autumn migration appears to be gradual, and to occur up to several months before spawning. Some information on the timing of inshore migration can be obtained from the timing of the former reduction fisheries which generally occurred as the stocks moved inshore. The fishery on the east coast of Vancouver Island usually occurred in November, and in the west coast inlets in January and December.

It appeared, therefore, that

(1) the first survey of the west coast of Vancouver Island in September would include the west coast of Vancouver Island stocks and the Strait of Georgia stock before any appreciable migration of herring into the Strait of Georgia had occurred;

(2) a survey of the same area in November would include only those stocks spawning on the west coast, while a survey in the Strait of Georgia would provide an estimate of that stock. In theory at least, the difference between the September and November west coast estimates should approximate the Strait of Georgia estimate; and

(3) a third west coast of Vancouver Island survey was planned for March when the mature west coast herring should be in the inlets spawning. An offshore survey at this time would then estimate the non-spawners or pre-recruit segment of the southern B.C. stocks, while a survey in the inlets would estimate the mature spawning segment of the west coast stocks. In addition to the southern B.C. herring, the late spring spawning Puget Sound herring may be present off the west coast in both autumn and winter.

The September survey would provide the longest lead-time but would provide a biomass estimate that would include both the Strait of Georgia and west coast stocks. The November surveys would provide a shorter lead-time but separate biomass estimates of the Strait of Georgia and west coast stocks. The success of the complete survey plan would depend on precise timing of three sets of cruises in relation to the migration of the herring stocks. Because of the need for advance scheduling of station vessels and the time required to charter, it was not possible to make last minute adjustments in the times of the surveys to take advantage of up-to-date information on herring movements. Success in timing was, therefore, probably more than could reasonably be expected.

Off the west coast of Vancouver Island in autumn and winter the species of fish in addition to herring that are likely to be encountered, and could be mistaken for herring, include hake, pollock, dogfish, rockfish and eulachon. The rockfish would consist mainly of two species, the yellowtail rockfish and the redstripe rockfish. The hake and pollock would not be expected to be a major problem for they form distinctive schools generally over deeper water than herring. Eulachon also would not be expected to be a particular problem for they, too, generally occur in the deeper water of the trenches and basins. Although the target strength of dogfish is about 1/20 or less that of a bony fish with an air bladder, this species is often present in relatively dense schools which are likely to return signals that could be mistaken for herring. Rockfish of both the above species present perhaps the greatest potential problem. Not only do they form schools that resemble herring schools, but they also occur in areas herring are known to frequent.

The G.B. REED was responsible for the hydroacoustic surveys off the west coast. On all three cruises she was assisted by a chartered trawler. The function of this vessel was to determine the species composition of the various major fish concentrations the REED encountered, to obtain samples of herring from which to determine the age, length, sex, and maturity compositions of the herring in the various parts of the area, and if weather and opportunity offered, to tag herring to determine to which spawning stock these herring belonged. The G.B. REED could have carried out all but the last function herself, but at the expense of a reduction both in the size of the survey area and of the number of tows. It was considered desirable to extend the survey area at least as far north as Estevan Point to ensure that as much as possible of the southern offshore feeding grounds were included within the survey area, and to make a large number of tows on which to base the identification of the species composition of the fish concentrations encountered.

The November survey in the Strait of Georgia and the March survey of Barkley and Clayoquot Sounds depended on a chartered trawler for the hydroacoustic survey and for any necessary fishing. In both cases neither was the survey area large enough, nor was the species composition likely to be so heterogeneous as to require full-time survey and fishing vessels.

II. MATERIAL AND METHODS

This report covers the five cruises which make up the 1980-81 offshore herring survey. Three of the cruises covered the continental shelf off the west coast of Vancouver Island from the Juan de Fuca Trench north to Estevan Point. These cruises were GBR80-7 and OK80-1 from September 9 to 26, 1980, GBR80-8 and HB80-1 from November 3 to 21, 1980, and GBR81-3 and MW81-1 from March 9 to 27, 1981. The fourth cruise, EH80-1, from November 3 to 21, covered the channels of the west side of the Strait of Georgia from Victoria to Campbell River, and the east side south to Jervis Inlet. The fifth cruise, HB81-1, from March 9 to 27, surveyed the inshore herring spawning areas of Barkley and Clayoquot Sounds. On each of the three offshore cruises, two vessels were used. The Canadian Government research vessel G.B. REED was responsible for the hydroacoustic surveys, and chartered trawlers for the fishing surveys. In September the OCEAN KING (Capt. J. Egeland) was used; in November the HOWE BAY (Capt. A. Orcutt); and in March the MARWOOD (Capts. F. Kohse, and C. Schule). On the November Strait of Georgia cruise, the chartered trawler EASTWARD HO (Capt. G. Sigmund) carried out the hydroacoustic survey and fished, while in the March Barkley and Clayoquot Sounds survey, the HOWE BAY (Capt. A. Orcutt) performed these functions.

A. HYDROACOUSTIC SURVEY

1. Area Coverage

The hydroacoustic surveys followed predetermined grids of track-lines. Off the west coast of Vancouver Island variations of the same basic grid were used on all three cruises (Fig. 1-7). The track-lines were laid out in the North-South direction to follow Loran A lines 10 μ sec. apart. The spacing thus varied from about 2.5 naut mi (4.6 km) offshore to about 4.6 naut mi (8.5 km) near shore. The north-south lines were arranged in blocks about 8 naut mi (14.8 km) long, such that each block required about a day to complete. Additional lines were added as required, equally spaced between the original lines. North of Amphitrite Point, where few fish were found, some track-lines, usually near shore, were omitted.

In the Strait of Georgia zig-zag track-lines were laid out covering all the major channels and areas off open shorelines out to the 50-fm contour (Fig. 8-11). In areas where herring were expected, a double zig-zag pattern was used, with the turning points approximately opposed. In the southern

and central strait the individual track-lines could not be illustrated because of overcrowding, so only the boundaries of the areas within which the lines lay are shown (Fig. 9, 10).

In Barkley Sound a rectangular series of track-lines was again used where possible (Fig. 12), laid out to fit the topography. In Imperial Eagle Channel the lines were spaced regularly one-half naut mi apart; off Loudoun Channel from one-half to three-quarters of a naut mi apart; and in Toquart Bay one-quarter to three-eighths of a naut mi apart. In other areas the spacing was irregular and dictated by the channel shape.

In Clayoquot Sound, with its inlet and channel topography, no regular pattern was possible for much of the area. Track-lines were laid out to cover the inlets and channels as effectively as possible (Fig. 13, 14). Outside the sound a regular series of track-lines a naut mi apart was laid out to cover the area out to the main offshore series of track-lines (Fig. 15). Very shallow areas such as Elbow Bank, Yellow Bank and Browning Passage were surveyed from a 25-ft. launch (Fig. 16) rather than from the trawler HOWE BAY.

All offshore track-lines were traversed at a speed of 9 knots during daylight hours, from about 0530 hrs to 1930 hrs local time. In the Strait of Georgia survey speed was 6-9 knots depending on the area surveyed, while in Barkley and Clayoquot Sounds the track-lines were run at 6 knots or less.

2. Integration System

(a) G.B. REED

On the three offshore cruises, the hydroacoustic measurements were made using a towed ceramic transducer[1], a Biosonics 101 echosounder (38 kHz) coupled to a Simrad EK-S dry-paper recorder and an Ecosonics digital echointegrator. The instrumentation and its interconnections are shown in the block diagram (Fig. 17). A simplified flow chart (Fig. 18) shows the path of the echo return signal as it is processed by the hardware and software of the system. The brief description of the integration system which follows is adapted from Taylor & Kieser (1980). The echosounder transmits a pulse (0.6 msec., 38 kHz, 1000 W) 50 times a minute vertically into the water, and then "listens" for echoes from fish and other targets. The return signal is amplified (5 kHz bandwidth, 20 log R time-varied gain or TVG) and displayed on a paper recorder. The return signal is heterodyned from 38 kHz to 8 kHz and fed to the echointegrator, and at the same time recorded on analog tape. After additional amplification, the root mean square (rms) value of the signal is detected in the integrator, then digitized, squared, integrated over a selected depth interval, and finally averaged over a specified number of transmissions. Normally the return echoes are integrated over 1 naut mi

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[1] The ceramic transducer used in September was lost on November 6. A replacement transducer of the same type was used thereafter.

(1.85 km) and for the depth intervals[2] 5-15 m, 15-20 m, 20-25 m, and then for depth intervals of 25 m to 300 m and of 50 m from 300 to 500 m or to the bottom.

At a speed of 9 knots the transducer towed at a depth of 18 m (10 fm). A small amount of back-radiation from the transducer resulted in an echo from the surface. The upper 25-m layer was divided into three so that the surface echo was isolated in the 15-20 m stratum. A bottom tracking buffer set the lower limit of integration at 3 m above the bottom, and provided good bottom tracking under most conditions. Over very irregular bottom with steep slopes it was at times necessary to increase the buffer to 10 m to enable automatic bottom tracking to continue.

(b) EASTWARD HO (Strait of Georgia) and HOWE BAY (Barkley and Clayoquot Sounds)

The echo integration system (Fig. 19) used on the EASTWARD HO in November, 1980, in the Strait of Georgia consisted of a Simrad EK38 Echosounder with nickel transducer, a Biosonics digital echointegrator, a digital magnetic tape recorder, an oscilloscope and a signal generator. These instruments are identified in Appendix I. The equipment was powered by 110 V, 60 Hz from the ship's generator.

Before the echosounder could be connected to the echointegrator, both instruments had to be converted to +5 V logic levels. In addition, the echosounder was modified to output the bottom pulse that activates the 'white line.' This bottom pulse was required by the echointegrator which had no bottom pulse detection circuit. The sounder also was equipped with a minute marker for the chart paper. The echointegrator was modified by the addition of a detector and 3 kHz low pass filter; this made it compatible with the 12 kHz echosignal from the echosounder.

The output from the Biosonics echointegrator was available on a small front panel printer; this output was also stored on a digital tape recorder for further analysis.

Originally a ceramic transducer, mounted in the standard torpedo-shaped towed body, was to be used on this cruise. However, on November 6 the G.B. REED lost her towed body and transducers. Since priority was given to the offshore survey the EASTWARD HO's underwater equipment was transferred to the G.B. REED. As an emergency replacement, a nickel transducer that had been used as a hull-mounted unit on the G.B. REED was rigged to a plywood depressor board. This unit would best be used by the EASTWARD HO, since this vessel would be operating in the relatively calm waters of the Strait of Georgia.

These replacements were tested by running track-lines in an area that had been surveyed previously. Both the echosoundings and the integration values obtained appeared reasonable. Daily tests of the electronic units showed apparently satisfactory performances of the echosounder when placed in the "test mode". These tests, however, do not assess the performance of the

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[2]The receiver's TVG starts at a distance of 5 m from the transducer so that the receiver is, in effect, suppressed for the first 5 m.

entire system including transducers. The only checks on the performance of the latter came from a visual inspection of the echosounder records--a method that will only detect very major gain changes. After the survey an attempt was made to calibrate the system at the Applied Physics Laboratory, University of Washington. It was found that the receiver was so unstable it was impossible to calibrate the system. This instability had been missed during the survey as it was not present when the sounder was operated in the "test mode". It was directly related to the replacement of the original ceramic transducer by a nickel one. The latter is less efficient than the former. To compensate, it was necessary to increase the gain of the sounder receiver, an act which led to the undetected instability. In addition, it was found during sea tests in March, 1981, that the efficiency of this nickel transducer declined drastically after it had been immersed in water for more than a few hours.

The instabilities in both echosounder and transducer not only made it impossible to calibrate the integration systems, but also made interpretation of the echointegration data meaningless.

A similar system (Fig. 20) was used on the HOWE BAY in March, 1981. Appendix I gives the instrument identification. The November cruise had shown that further changes to the echosounder and echointegrator were required to enhance stability and bottom tracking. Thus the Simrad Echo Sounder was modified to receive the bottom pulse that was now generated in the echointegrator. In addition, an internal CW or pulsed calibration source was installed.

The echointegrator was equipped with the following features:

- A new precision detector and 2.5 kHz RC type low pass filter for the signal channel;
- a variable threshold bottom trigger circuit and an optional 300 Hz low pass filter to enhance the bottom echo for bottom detection;
- an adjustable delayed pulse for manual bottom tracking; and a gate circuit to reject false bottom pulses that are generated by dense fish schools.

Without the gate function a signal that exceeds the bottom pulse threshold cannot be integrated. The gate circuit was designed to select the first bottom pulse that would occur within the bottom window (a logic pulse of selectable width that is set by the preceding bottom pulse). When the bottom pulse is missing, all subsequent transmit trigger pulses will be suppressed until the operator resets bottom tracking. This is required to avoid integration of the bottom echo. Even with these modifications the echo integrator is difficult to operate as it will stop when only a single bottom pulse is missed. This becomes a problem in rough weather when echo returns are suppressed by transducer aeration, or when the bottom echo is weak over steep, acoustically poor reflecting bottom. The echointegrator's software will have to be modified to overcome these problems.

On the HOWE BAY the transducer was supported by a ladder-shaped aluminum frame that fastened amidships over the port side. The transducer was mounted on an aluminum plate. As a precaution against flow noise, the transducer face was set flush with the bottom of the plate; no additional precautions were taken to reduce ship's noise. The transducer was held 1.5 m below the surface and oriented to look directly downward.

During the March, 1981, cruise, an attempt was made to survey some shallow areas in Clayoquot Sound from a 25-ft launch. The echo sounder, echo integrator and oscilloscope were secured in the cabin. The transducer was held by a small aluminum frame and secured on the starboard side. Its face was 0.5 m below the surface and level at low speeds. At survey speeds of 3 to 4 knots, it looked forward by 5 degrees. The instruments were powered by a 500-W gasoline generator that was mounted on the roof. It was found that the signal to noise ratio was acceptable to a maximum depth of approximately 100 m.

3. Integration Data Processing

The output of the echo integrator is proportional to the average echo intensity ($\bar{I}_{mn}$) taken over the m^{th} depth interval and n consecutive transmissions, and is given by the following equation:

$$\bar{I}_{mm} = TL + \overline{TS}_{mn} + VR + SL + KTVG + KMAX + RMAX + \Psi + 10 \log \frac{c\tau}{2} + 10 \log \bar{\rho}_{mn}$$

where the terms on the right in order are: transmit level, average target strength, voltage response, shell loss from the towed body cover, TVG correction factor, gain, maximum TVG range term, beam factor, depth slice (Δr) and average fish volume density. All terms are in decibels[3]. A more detailed discussion of these terms is given in Appendix I of Taylor and Kieser (1980), and the values used on the present cruises are given in Appendix I of this report.

As target strength is dependant on species and size, the equation is solved for:

$$10 \log \bar{\rho}_{mn} + \overline{TS}_{mn} = \bar{I}_{mn} - TL - VR - SL - KTVG - KMAX - RMAX - \Psi - 10 \log \frac{c\tau}{2}$$

All quantities on the right-hand side are known. A computer program (written in BASIC) is used to obtain from average intensities, $\bar{I}_{mn}$, for selected depth intervals the average intensity for major depth strata. For this series of cruises only one stratum was used, from 25 m to the bottom, or to 250 m. The TVG correction factor for each depth interval is entered in this program. The remaining factors are independent of depth and reduce to a single factor, also entered. The program then computes the product of target strength, fish density (per unit volume) and average depth of the interval to give target strength fish density per unit surface area. These values will be referred to as the relative fish density per unit surface area. They are plotted for each printout interval[4] along the track-line, and contoured at intervals of powers of 10. An additional contour (0.3×10^{-6}) was added to form a boundary above which the integral is the result of fish but below which essentially no fish are found, and noise becomes predominant.

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[3]A decibel is 10 times the logarithm of an intensity ratio.

[4]The printout interval was every 333 transmissions, and at 50 transmissions per minute is equivalent to 1 naut mi (1.8 km) at 9 knots.

The resulting charts (Fig. 21-32) are the basis of the estimation of the quantities of the various species present. The areas of sections of the survey area within the boundary contour were measured by planimeter. The average relative fish density per unit surface area within each such area was determined. Since the equipment in use cannot measure in situ target strength, this parameter has been estimated from formulae which express target strength per kilogram in relation to length for fish with and without swim bladders. The formulae (Appendix I) are based on data obtained from the literature.

From the estimated target strength per kilogram for each species, and from the average species composition (Table 1), the average target strength per kilogram was obtained for each area or major fish concentration. The total quantity of fish within an area or concentration is given by the product of the planimetric area and the average fish density-target strength value per unit surface area divided by the average target strength value per kilogram for that area or concentration. The quantity of each species present is inferred from the species composition.

B. FISHING SURVEYS

1. Fishing Methods

The fishing surveys on the three west coast cruises in September, November, and March were carried out by chartered trawlers. The G.B. REED made some tows in September and in March. Table 2 summarizes some characteristics of the vessels, the types of net, and fishing equipment used.

Midwater trawl tows (Fig. 33-36) were made to identify the species of fish responsible for the concentrations encountered on the hydroacoustic surveys and to provide basic biological information on the species encountered. On all cruises fishing effort was concentrated on those areas considered to contain herring. Tows were made in other areas to confirm the evidence from echosounder records that they did not contain herring. Further tows were made in such areas only if time permitted. The result is that in some cases the species composition of non-herring concentrations is not estimated with a very high degree of reliability.

The common and scientific name (Table 3) of all species encountered on the five cruises covered in this report follow Hart (1973).

2. Sampling Methods

The entire catch of each tow was sorted by species into tubs of about 45 kg (100 lb) capacity. Six tubs of each species, two from the beginning, middle, and end of the sort were selected at random for weighing and sampling. The remaining tubs of each species were counted and discarded. If there were less than six tubs of a species, all were weighed and set aside for sampling. Every effort was made to avoid large catches by terminating the tow when sufficient fish were "seen" on the netsounder to have entered the

net. Sometimes large tows of herring, or hake or dogfish, could not be avoided. For such tows, usually only the first split was sorted and weighed. The weights of the remaining splits were estimated and either brought aboard or released, depending on the species.

The main fishing and sampling effort was devoted to herring. Two or more samples each of over 100 fish were frozen for processing later in the laboratory.

Length-sex samples of other species, such as hake, pollock, yellowtail and redstripe rockfish and dogfish were taken as time and opportunity permitted. All salmon, primarily chinooks, were weighed, measured, and the stomach contents examined.

Davenport and Harling's (1965) method of measuring fish was used. On all fish except dogfish and herring, fork length was measured to the nearest centimetre. For dogfish, total length was measured to the nearest centimetre. In herring, the length to the end of the silvery area of the caudal peduncle was measured to the nearest millimetre. All herring samples were processed under contract. Length, sex, degree of maturity, and age were determined for 100 fish samples. In some cases, two or three samples from one tow were worked up.

III. RESULTS

A. CATCH COMPOSITION

Details of the tows and of the catches made off the west coast of Vancouver Island by the OCEAN KING in September, 1980, have been published by Barner, Taylor and Turner (1982), by the HOWE BAY in November, 1980, by Barner, Turner and Taylor (1982), and by the MARWOOD, HOWE BAY and G.B. REED in March, 1981, by McCarter, Barner and Taylor (1982), and in the Strait of Georgia by the EASTWARD HO in November by Barner, Kieser and Taylor (1982).

1. West Coast of Vancouver Island

(a) In September, the OCEAN KING made 61 midwater tows (Fig. 33, Table 4). Most of the fishing was on the major herring concentrations. Only 12 tows were made in hake and pollock concentrations and 4 tows in rockfish concentrations. The five large concentrations along the outer edge of the continental shelf from the Juan de Fuca Trench[5] to north of the Barkley Canyon proved to be almost entirely herring. The average total catch rate ranged from 434 kg/hr off Barkley Canyon to 3,510 kg/hr off the Nitinat Canyon. Most of the tows (20) were made in the latter area, where individual catches of

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[5]The names of the topographic features referred to in the text are shown on the charts of fishing positions (Fig. 8, 33, 34, 35).

herring ranged from 0 to 7,203 kg in 30-minute tows. Inshore, 2 tows were made on La Pérouse Bank along the edge of the Barkley Basin, and 3 tows on Swiftsure Bank. In the former area the average total catch rate was 340 kg/hr, while in the latter area it was 7,645 kg/hr, mainly due to one large catch of herring. Redstripe rockfish was an important contributor on La Pérouse Bank, while on Swiftsure Bank dogfish was. Hake predominated in the catches in Barkley Basin, Cape Beale Basin, and along the steep eastern edge of the Prairie Grounds[6] to the Juan de Fuca Trench. Catches were largest in the Cape Beale Basin and on the Swiftsure Spit (4,433 kg, and 2,456 kg, respectively). Pollock was a major contributor in 3 of the 4 areas, with catches of 87 to 352 kg. Two species of rockfish were commonly encountered in relatively small amounts. These were the redstripe and the yellowtail rockfish. The former was the more widespread and occurred on the Cape Beale Spit and on the Southwest Corner. The yellowtail rockfish was more generally distributed but was not caught in as large amounts. The largest catch was 130 kg compared to 1,730 kg for the redstripe rockfish.

(b) In November the HOWE BAY made 42 midwater trawl tows (Fig. 34, Table 5). Again most of the fishing effort (27 tows) was directed towards the herring concentrations on the outer edge of the continental shelf. Six tows were made on the Southwest Corner of La Pérouse Bank, on the Finger Bank, and on Swiftsure Bank. There were 6 tows in the hake and pollock concentrations in Barkley Basin, along the eastern edge of the Prairie Grounds, and two on the small rockfish concentrations in these areas.

Catches from the concentration on the outer edge of the shelf between Barkley and Nitinat Canyons were mainly redstripe and yellowtail rockfish. The average total catch rate based on 6 tows was 2,198 kg/hr. The total catch rates of the individual hauls varied from 96 to 9,984 kg/hr. Individual catches of the redstripe rockfish varied from 4 to 806 kg, and of the yellowtail rockfish from 2 to 178 kg. There were 9 tows made in the large concentration stretching from the Nitinat Canyon to the Finger Bank. Herring was the predominant species. They occurred in 8 of the tows, with individual catches from 7 to 18,832 kg. Dogfish ranked second; they occurred in 8 tows, the individual catches ranged from 167 to 1,015 kg. Yellowtail rockfish were third and occurred in 7 tows in amounts from a trace to 293 kg. Small quantities of pollock but no hake occurred in some catches in this area. South of the Nitinat Canyon to the Juan de Fuca Trench there were 6 tows. In 5, the catches were a mixture of herring and dogfish, while the last was mainly yellowtail and widow rockfish. On the Finger Bank herring was the major species. On Swiftsure Bank the catches were a mixture of herring and dogfish. Three tows in Barkley Basin yielded 619 kg of hake, 1,201 kg of pollock, 254 kg of rockfish, mainly yellowtail, and 45 kg of dogfish. Along the eastern edge of the Prairie Grounds 4 tows yielded 311 kg of hake, 161 kg of pollock and small amounts of dogfish and rockfish. Small schools of yellowtail rockfish apparently occurred on the edges of the hake concentrations.

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[6] In the older charts of the southwest coast of Vancouver Island where depths are given as fathoms, this feature appears as a northward projecting arm of the Juan de Fuca Trench followed by a series of small depressions. On the modern metric charts this region appears as a steep edge on the eastern side of the Prairie Grounds.

In the single tow in Trevor Channel the catch rate was over 8,000 kg/hr, and the catch predominantly hake (93%). The remainder was pollock and dogfish.

The catches in November were interesting in that they showed the presence of considerably more rockfish and dogfish along the outer edge of the shelf than in September. The rockfish were mainly the redstripe in the northern part of the area near Barkley Canyon, and the yellowtail in the southern part near the Juan de Fuca Trench. The dogfish were mixed with the major herring concentration off Nitinat Canyon and to the south. Although they were present, no large catches of dogfish were made inshore on the Finger Bank or on Swiftsure Bank. Hake catches had declined sharply from September. The catches of this species were largest in Barkley Basin although pollock catches here were twice those of hake. Along the eastern edge of the Prairie Grounds catches were smaller, but hake outnumbered pollock 2:1.

(c) In March, in addition to the MARWOOD, which made 27 tows, the G.B. REED and HOWE BAY fished after completing their hydroacoustic surveys, and made 14 and 19 tows, respectively (Fig. 35, 36, Table 6). The G.B. REED fished along the outer edges of the continental shelf, and along the northern edge of the Juan de Fuca Trench. The HOWE BAY made 5 tows in Barkley and Clayoquot Sounds and 14 tows on the inshore grounds (the Southwest and Southeast Corners, the Finger Bank, Barkley and Cape Beale Basins and the eastern edge of the Prairies). The MARWOOD concentrated mainly on the Juan de Fuca Trench, and inner edge of the Prairie Grounds, the Swiftsure Spit and Bank, but also made some tows on the outer edge of the shelf, on the Finger Bank, and in Barkley Basin.

Along the outer edge of the continental shelf from the Juan de Fuca Trench to Estevan Point, the catches made were primarily herring with some dogfish. The latter were more common south of Nitinat Canyon. Catch rates in this area were generally low, less than 500 kg/hr. The herring schools encountered were small but active. They tended to dive and avoid the net. Few herring were caught on the Southwest and Southeast Corners of La Pérouse Bank. On the Finger Bank and in the Cape Beale Basin dogfish were very abundant resulting in 2 large catches of 18,000 and 23,000 kg. In Barkley Basin pollock were the predominant species. No hake were caught on this cruise. On Swiftsure Bank the catches were a mixture of herring and dogfish. The herring catches did not seem to be proportional to the abundance of herring indicated on the sounder. The herring were perhaps able to dive under the MARWOOD's net.

The MARWOOD also made 3 tows in the entrance to Juan de Fuca Strait. The catches were relatively small; in 2 tows dogfish was the main species, while in the third pollock was. Small amounts of herring occurred in all three.

The HOWE BAY made 1 tow in Trevor Channel in Barkley Sound and 4 in Clayoquot Sound (2 in Millar Channel and 1 each in Sydney and Tofino Inlets). The catch in Trevor Channel was a mixture of hake and dogfish, while in Millar Channel and Sydney Inlet the catches were predominantly hake with small amounts of dogfish and rockfish (mainly yellowtail). The best catch of hake was near the mouth of Millar Channel. The catch in the upper part of this channel was considerably smaller. There was also a difference in the size

composition of the hake in the 2 tows, with small fish occurring near the mouth.

Herring, as in September and November, were again caught mainly on the outer edge of the continental shelf. Good catches were also made on Swiftsure Bank. While hake were caught in some of the inlets, none were caught along the eastern edge of the Prairie Ground or in the Juan de Fuca Trench--areas where they had been taken in quantity on the September and November cruises. The G.B. REED did locate what appeared to be a typical hake layer in the Juan de Fuca Trench but the fishing vessel failed to relocate this layer. Pollock continued to occur in the catches from Barkley Basin. Dogfish were very numerous in the inshore grounds, i.e. the Finger Bank, Cape Beale Basin and Swiftsure Bank. In November, the largest catches of this species had occurred among the herring concentrations from the outer edge of the shelf to the Finger Bank. The catches of rockfish were smaller than in November, the two largest catches, both of the yellowtail rockfish, were on the Southwest Corner (573 kg) and along the eastern edge of the Prairies (612 kg).

2. Strait of Georgia

In November the EASTWARD HO made 23 midwater trawl tows (Fig. 8, 9, 10, 11, Table 7) in the Strait of Georgia to identify the fish concentrations encountered during the hydroacoustic survey of this area. The tows were made in the southern part of the Strait from the Victoria area through the island passages to Crofton and Yellow Point, and in the northern part in Deepwater Bay, off Lund, and in Jervis Inlet. The catches were almost entirely herring from Victoria to Trincomali Channel and were good in all areas except Plumper Sound, Satellite Channel, and part of Swanson Channel. In Stuart Channel, off Crofton, dogfish and hake were predominant, and only small amounts of herring were taken. However, off Coffin Point during the first half of the cruise herring were predominant, although dogfish were present in the catch. At the end of the cruise the herring could not be relocated, and a tow off Yellow Point consisted mostly of dogfish. Good catches of herring were made in Deepwater Bay. Dogfish were plentiful and formed from one-quarter to one-third of the catch. Off Lund and in the entrance to Jervis Inlet the catches were 62% pollock and 30% hake, and 83% pollock and 15% hake, respectively.

B. TAGGING AND TAG RECOVERIES

Herring were tagged offshore in September both by midwater trawler and by seiner (Haegele pers. comm.). The OCEAN KING tagged from 3 tows; 729 herring from tow 31, 879 from tow 41; and 1,307 from tow 50. These 3 tows were on the outer edge of the continental shelf near the Nitinat Canyon (Fig. 33). Barner, Taylor and Turner (1981) have described the method used in tagging herring from a midwater trawl. The seine taggings were inshore on the Southeast and South Corners of La Pérouse Bank, and on Swiftsure Bank.

Three recoveries were made from the trawl taggings, one on March 8 from Cook Channel in Nootka Sound, one on March 15 from Maurus Channel in Clayoquot Sound, and one for which no recovery information was provided. The seine and trawl taggings yielded proportionatly the same number of recoveries. This would indicate that, provided the sea is relatively calm and the herring are not concentrated in the codend, trawl-caught herring can be tagged as successfully as seine-caught fish. However, the small number of recoveries limit the value of any inferences.

Recoveries from the seine taggings on the Southeast Corner were from Lambert Channel in the Strait of Georgia, from Cook Channel in Nootka Sound and from off Barkley Sound. One recovery from a tagging on Swiftsure Bank was from Stuart Channel in the Strait of Georgia. A recovery was also made from the stomach of a salmon caught on La Pérouse Bank. A recovery of a herring tagged off Comox Bar on March 10 was made 16 days later by the G.B. REED on the outer edge of the continental shelf south of Nitinat Canyon (GBR81-3-14, Fig. 35). The tag recoveries, while few in number, confirm the movement of herring from the west coast of Vancouver Island into the Strait of Georgia. They also suggest that fish spawning in Nootka Sound, north of Estevan Point may summer south of Amphitrite Point, both on La Pérouse Bank and on the outer edge of the shelf south of Nitinat Canyon.

C. FISH DISTRIBUTION AND BIOMASS

1. Herring

(a) Offshore, West Coast of Vancouver Island

Off the west coast of Vancouver Island from the Juan de Fuca Trench north to Estevan Point approximately 67,740 t[7] of herring were encountered in September, 1980 (Table 8), 53,700 t in November (Table 9) and 33,465 t in March, 1981 (Table 10). Most of the herring occurred south of Amphitrite Point. In September, only 5,630 t (8%) occurred to the north to Estevan Point, in November 2,900 t (5%), and in March about 5,775 t (17%).

(i) In September, the major herring concentrations lay along the outer (100 fm) edge of the Prairie Grounds from the Juan de Fuca Trench northwards for about 45 naut mi to approximately the latitude of Pachena Point (Fig. 21). The concentrations extended shorewards towards the 50-fm contour about 10 naut mi in the north, and 10-15 naut mi in the south. Schools in this area were estimated to contain 48,990 t (Table 8), 31,030 t or 63% south of the U.S.-Canadian fishing boundary. Smaller concentrations occurred inshore on the Southwest and Southeast Corners of La Pérouse Bank (6,260 t), on Swiftsure Bank (2,720 t), on the Swiftsure Spit (190 t), and mixed with the major hake and pollock concentrations (3,840 t). Most of the herring occurred along the 50-fm contour, usually in areas where the slope was steep. No herring were found on the tops of the banks, away from the edges. Of the herring in these small concentrations 2,940 t (22%) occurred south of the U.S.-Canadian fishing boundary. Of the total amount of herring located, 33,970 t (50%) occurred south of this boundary.

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[7] Metric tons (t) of 1,000 kg or 2,205 lbs are used throughout this report.

North of Amphitrite Point, the continental shelf is straighter, less indented, and generally gently sloping, unlike to the south where the shelf is indented by canyons and cut by trenches and gullies, some steep-sided, some gently sloped. In this northern area, the fish schools encountered were small, scattered and less dense than those to the south. From their appearance on the echosounder paper all were assumed to be herring. Five concentrations (5,630 t) were located, four associated with the 100-fm edge, and extending as narrow bands towards the 50-fm contour (Fig. 22). No schools were located inside the 50-fm contour. The five concentrations occurred in an area of 496 km^2. While this area is 41% of that occupied by herring south of Amphitrite Point, the average intensity was only 23% of that in the southern area, so that the region contained only 8% of the herring.

On the first day of the September cruise a short hydroacoustic survey was carried out off Victoria. This was not a scheduled part of the cruise but was required to check the operation of the system after a computer breakdown. The area surveyed (Fig. 32) was between Race Rocks and Victoria Harbour, shorewards of Constance Bank. The survey was carried out upon leaving Victoria, from 1815 hrs until 2245 hrs. It was ended when the fish rose to the surface after dark. The survey covered an area of 77 km^2, involving 39 naut mi of track-line. A large dense school of fish was located between Albert Head and Victoria. Smaller schools were found between Albert Head and William Head. Because of the limited time, the boundaries of the fish concentration were not defined, and lay outside the surveyed area. The appearance of the schools on the echogram and their behaviour at dusk was typical of herring.

There were calculated to be 10,480 t of herring in the survey area. Because of the limited survey, this is a minimum estimate of the amount of herring in the Victoria-Race Rocks area. The presence of a body of herring of this size here at this season suggests that the migration of herring from the offshore summer feeding grounds had already begun.

(ii) In November, 1980, the herring biomass offshore (Table 9) was estimated to be 53,700 t, a decline of 14,040 t (21%) from September. Although most of the herring (39,610 t or 74%) were still offshore between the 100-fm contour marking the outer edge of the continental slope and the 50-fm contour marking the edge of the coastal banks, the distribution of the major concentrations had changed markedly (Fig. 23). Only 12,370 t (33%) were to be found offshore south of the U.S.-Canadian fishing boundary, compared to 31,030 t (63%) in September. The largest concentration (23,900 t) lay to the north of the Nitinat Canyon, and stretched inshore almost to the east end of the Finger Bank. In September the largest concentrations (26,500 t) was south of this canyon. Inshore, the quantity of herring on Swiftsure Bank and along the 50-fm contour running north from it had increased to 9,110 t from 2,720 t. The quantity on the Southeast and Southwest Corners had declined to 3,520 t from 6,260 t, and the quantity south of the Juan de Fuca Trench had increased somewhat from 2,320 t to 3,100 t.

From Amphitrite Point north to Estevan Point (Fig. 24) the quantity of herring found had declined from 5,630 t in September to 2,900 t in November. While herring were found in the same general areas as in September, and most still occurred between the 50- and 100-fm contours, the concentrations were more dispersed with some small groups shorewards of the 50-fm contour.

(iii) In March, the hydroacoustic survey south of Amphitrite Point was carried out from the 10th-17th, north of Amphitrite Point from the 18th-21st, and on Swiftsure Bank on the 23rd. Fisheries occurred in Area 23 (Barkley Sound) on March 11 (seine) and on March 15 (gillnet) and in Area 24 (Clayoquot Sound) on March 15 (gillnet). Spawning was reported in the former area from March 17-21, with a peak about March 19, and in the latter area from about March 12, peaking about March 15. Some earlier spawnings had occurred in the northern part of Area 24 in February and on March 8-9. Thus the survey south of Amphitrite Point was completed before the peak of the spawning in Barkley Sound. Spawning in Area 24 however had occurred before the survey of the area north of Amphitrite Point, and before much of the survey south of that point.

The offshore survey in March can be expected therefore to include those fish that did not spawn in 1981 as well as spawned-out fish from Area 24 and some spawned-out fish from Area 23, and perhaps also from the Strait of Georgia. The total amount of herring located offshore outside the inlets in March (Table 10) was 33,465 t, of which 5,775 t occurred north of Amphitrite Point (Fig. 25, 26). A feature of herring distribution over the entire area in March was the widespread occurrence of small scattered schools. From the text table below it can be seen that the total area over which herring concentrations occurred in March was much greater both north and south of Amphitrite Point, and the average density much less. The numbers in parentheses in the table below are ratios relative to the September data.

Month	South of Amphitrite Point		North of Amphitrite Point	
	Area (km^2)	Density	Area (km^2)	Density
September	1217 (1.0)	.2397E-4 (1.0)	496(1.0)	.5447 (1.0)
November	1283 (1.05)	.2624E-4 (1.09)	210 (0.42)	.5224E-4 (0.52)
March	2504 (2.06)	.6417E-5 (0.27)	1495 (3.06)	.2856E-5 (0.52)

The major concentrations again lay on the outer half of the shelf mainly between the 50- and 100-fm contours. However, in contrast to the 2 previous cruises they appeared to form an almost continuous band from the Juan de Fuca Trench to Estevan Point. There were 5,370 t (31%) south of the U.S.-Canada boundary line, 6,550 t (38%) north of the line as far as Amphitrite Point, and 5,775 t (34%) north of Amphitrite Point. The offshore area south of the border occupied by herring was about the same as in September and about 5.7 times that in November, but the quantity of herring present was only about 16% of that in September, and about one-half that in November. The area occupied by herring schools inside the 50-fm contour was larger than on the other 2 cruises, 613 km^2 north of the U.S.-Canada fishing boundary, and 301 km^2 south, compared to 275 km^2 and 331 km^2 in November and 199 km^2 and 96 km^2 in September.

The quantity of herring inside the 50-fm contour was also greater than on the other 2 cruises. There were 11,580 t north of the boundary and 4,195 t south. The largest concentration found during the entire cruise was on Swiftsure Bank (12,300 t), about two-thirds on the Canadian side. In November there had been 7,900 t on Swiftsure and in September only 2,720 t. Herring were also spread over a much larger area of La Pérouse Bank than on the previous two cruises. The schools were, however, small and dispersed so that the actual quantity of herring was less than on previous cruises.

(b) Barkley and Clayoquot Sounds

An inshore hydroacoustic survey of Barkley and Clayoquot Sounds was conducted at the same time as the March offshore survey. Barkley Sound was surveyed between March 12 and 14 and Clayoquot Sound between March 15 and 21. A repeat survey of Trevor Channel was made on March 24. The results of this survey, although expressed in tons, should be regarded as qualitative because of a series of equipment problems.

In Barkley Sound (Fig. 27), herring were found on the west side, in Toquart and Mayne Bays, Sechart Channel, and Macoah Passage, but only in small amounts (215 t). None were found in Imperial Eagle or Loudoun Channels. The total for the sound was 231 t (Table 11).

In Clayoquot Sound (Fig. 28 and 29) just under 600 t were located. Of this, 127 t occurred immediately outside the sound, and was made up of 11 t off Lennard Island, 18 t off Father Charles Channel, 28 t off Russell Channel, and 70 t off Sydney Inlet. On the spawning grounds about 470 t were located, 139 t in the Meares Island area, 160 t in the Bawden Bay/Whitepine Cove area and 172 t in Sydney Inlet.

The echointegration system used in the inshore survey was deemed less reliable than that used offshore. It was a second system based on a commercial echosounder and nickel transducer, and an echointegrator still undergoing development. Calibration after the cruise showed that the echosounder system was inherently unstable probably because of necessary modifications to accommodate the integrator made shortly before the cruise. Experience during the cruise revealed that the echointregrator would require extensive re-programming before it was likely to operate satisfactorily.

Taking into account the equipment problems the amount of herring located still was lower than anticipated. This was especially the case in Barkley Sound where the survey occurred before spawning and before the gillnet fishery (but not before the seine fishery). The problem appeared to be one of not locating fish rather than of measuring incorrectly the fish located. The hydroacoustic surveys were carried out by day rather than by night. This may account to some extent for the small amount of fish found. No herring were found in the usual prespawning holding area in the outer or southwestern part of Imperial Eagle Channel, and only small amounts were found in the vicinity of the actual spawning areas. It is possible that herring were moving through the island group separating the 2 areas. This area was not surveyed.

It was not unexpected that only small quantities were found in Clayoquot Sound, since herring move offshore rapidly after spawning, and this had occurred before the area was surveyed.

In Clayoquot Sound some of the very shallow localities such as Elbow Bank, Yellow Bank, Browning Passage, Lemmens Inlet and the area around Stockholm Island were surveyed on March 1, 1981, using a 25-ft launch (Fig. 30). Few herring remained since spawning had occurred several days previously. In the Stockholm Island-Browning Passage area 3.2 t were located, while in the Meares Island area 11.3 t were found. While few fish were located, the test showed it was practical to conduct echointegration surveys

in this manner, although the problems of navigating a small boat in shallow water, in strong tides, and along fixed track-lines proved more difficult than anticipated.

(c) Strait of Georgia - November

The hydroacoustic survey by the EASTWARD HO in November in the Strait of Georgia was designed to complement the concurrent November survey off the west coast of Vancouver Island.

During the first two days of this survey the EASTWARD HO used a ceramic transducer in the standard towed body. During this time, Swanson Channel, Prevost Passage, Satellite Channel, Sansum Narrows, and Stuart Channel were surveyed. On November 6, the underwater units were transferred to the G.B. REED and replaced by emergency units. From November 9-20, track-lines were run over the remaining areas of the Strait (Fig. 8-11). The emergency units were later shown to be defective. The echointegration data gathered when they were used were therefore useless. All that was possible was a visual interpretation of the echosounder records which indicated where herring were concentrated, and confirmed the results of the test fishing.

(d) Discussion

(i) Biomass estimates

It has long been presumed that the Strait of Georgia herring feed in summer off the lower west coast of Vancouver Island, together with stocks spawning in Barkley and Clayoquot Sounds and perhaps with herring spawning in Puget Sound. The 3 cruises were planned to occur at a time when all herring summering off the lower west coast should be in the area (September), at a time when the Strait of Georgia population had migrated into the Strait (November), and at a time when the Barkley and Clayoquot Sounds herring were spawning (March), and the only herring offshore would be the non-spawners, perhaps some recovering spents and perhaps the relatively small, late spawning Puget Sound stock. Since the trips were scheduled 6-9 months in advance, there was no assurance that this schedule would coincide completely with the actual phases of the inshore migration.

The three hydroacoustic surveys off the west coast should, therefore, yield herring biomass estimates of different sizes since they occurred at different stages of the spawning migration. The September estimate (67,740 t plus an additional 10,480 t off Victoria) was expected to be the largest, the November estimate (53,700 t) intermediate, and the March estimate (33,465 t) the smallest. The September survey may have underestimated the combined Strait of Georgia and west coast stocks, for the presence of a considerable body of herring off Victoria suggests that migration into the Strait may have begun before the start of the survey. If the presence of more herring on Swiftsure Bank in November than in September indicates emigration was not complete, the November survey may have overestimated the west coast stocks. Since mainly spent fish were found offshore in March, the estimate from this survey does not represent the non-spawning segment of the populations, but only the west coast and Strait of Georgia spawners that had returned offshore by the time of the survey.

Sampling indicated that the stocks on all surveys consisted mainly of mature or spent fish. No large amounts of immature herring (1- or 2-yr-olds) were encountered.

(ii) Distribution

The major feature of herring distribution off the lower west coast of Vancouver Island is the concentration of this species from Amphitrite Point south to the Juan de Fuca Trench, mainly on the outer part of the shelf between the 50- and 100-fm contours. Smaller concentrations were usually to be found inshore along the 50-fm edge, on the Southwest and Southeast Corners of La Perouse Bank, on Swiftsure Bank, and along the Washington coast south of the Juan de Fuca Trench.

Major differences in distribution and biomass occurred on the 3 cruises in September, November, and March, probably as a consequence of spawning migration. In November the major changes in distribution were the disappearance of most of the herring from the southern Prairie Grounds, south of the U.S.-Canada fishing boundary, and the increases in the quantity to the north and inshore, especially on Swiftsure Bank and south of the Finger Bank. It would appear that the herring may have moved northward across the boundary as well perhaps as inshore along the Juan de Fuca Trench to Swiftsure Bank and then presumably into the Strait of Georgia. The decline in herring biomass between September and November suggests that some fish had moved out of the area. However, the concentrations still remaining on Swiftsure Bank and along the Juan de Fuca Trench suggest that this migration may not have been complete at the time of the November survey. North of Amphitrite Point there was still little herring to be found.

In March there was again a marked change in the distribution pattern. Herring were widely distributed in small scattered schools. The main features were the almost continuous but relatively light concentrations running from the Juan de Fuca Trench north to Estevan Point, the presence of herring within the 50-fm contour over a much wider area than on the previous two cruises, and the presence of a large concentration on Swiftsure Bank. Since the total herring biomass was only about one-half that in September and a little over 60% that in November, apparently a large proportion of the population was not in the area but on or near the inshore spawning grounds. The large concentration on Swiftsure Bank and the widespread concentrations immediately north and south of the Juan de Fuca Trench suggest that Strait of Georgia herring may have been migrating offshore during the period of the survey. The presence of small schools over a wide area north of Amphitrite Point suggest that herring were moving south from the spawning grounds in Area 24 (Clayoquot Sound and Sydney Inlet) and perhaps Area 25 (Nootka Sound) as well as from Area 23. Some support for these speculations is also provided by the small number of tag returns mentioned earlier.

(iii) Comparison to existing estimates

The comparison of the hydroacoustic estimates with those by existing independent methods would be valuable if the errors associated with such methods have been thoroughly examined and the limits of accuracy determined. If the errors of the independent estimates have not been examined, the comparison does little to establish the validity of either hydroacoustic or

independent methods. It may result in a somewhat greater, although not always justified, feeling of confidence in both, since agreement would indicate that the biasses were probably not extreme, or, less likely, were in the same direction in all methods.

Two independent estimates are available, one based on catch, sampling, and spawn deposition data (Hourston 1981), the other on the pre-fishery echosounder survey (Anon. 1981). The errors associated with these methods have not been stated, but intuitively would be expected to be large because of the types of data on which they are based.

Abundance Estimates (metric tons) from Catch, Sampling and Spawn Deposition Data. (Hourston 1981, Table 1.)

West Coast		Strait of Georgia	
Management Unit	Abundance	Management Unit	Abundance
West Barkley	14,000	Powell River	13,100
Other Area 23	+	Nanaimo-Comox	92,000
South Clayoquot	25,800	Yellow Point	19,500
Other Area 24	1,800	Ganges-Plumper	2,000
Nootka Sound	5,000	Other Vanc. Isl.	400
Nuchatlitz Inlet	10,600		
Total	57,200	Total	127,000

Abundance Estimates (metric tons) in 1981 from the Pre-fishery Echosounder Surveys.

West Coast		Strait of Georgia	
Area	Abundance	Area	Abundance
Area 23	16,300	Area 14	27,200-36,300
Area 24	15,900	Areas 17, 18	18,100-27,200
Area 25 (Nootka)	4,500-6,400		
(Nuchatlitz)	10,000		
Total	46,700-48,600	Total	45,300-63,500

The November hydroacoustic estimate of 53,700 t agrees reasonably with both the alternate estimates for the Areas 23 to 25 (57,200 t and 46,700-48,600 t). However, it is not clear whether the Nuchatlitz and Nootka abundances should be included. These areas are north of the hydroacoustic survey boundary of Estevan Point. There are some indications from tag returns that after spawning at least some Nootka fish occurred within the survey area. The hydroacoustic estimate contains a contribution of 9,100 t from Swiftsure Bank. It is conceivable that some of this may be herring bound for the Strait of Georgia. Excluding these fish reduces the hydroacoustic estimate to 43,590 t. This is less than the comparable independent Barkley Sound to Nuchatlitz estimates but corresponds to them if the Nuchatlitz component is excluded (e.g. 46,600 t and 36,700-38,500 t, respectively).

The September hydroacoustic estimate (78,220 t) is less than either of the independent estimates for Barkley Sound and the Strait of Georgia combined (184,200 t and 92,000-112,100 t, respectively). The hydroacoustic estimate may be a minimum estimate, as herring may have been migrating into the Strait of Georgia at the time of this survey. On the other hand, the independent estimates may be too high, for not all the herring in the Strait of Georgia may enter from the south--and so have summered off the west coast. Some, especially of those in the northern part, may enter from the north through Johnstone Strait (Taylor 1964). In the pre-fishery sounder survey, it is not clear whether the herring in Area 14 surveyed in March are the same as those in Areas 17 and 18 surveyed in November. If they are, then only one or the other of the estimates should be included. This results in a combined west coast and partial Strait of Georgia estimate of 73,900-84,900 t, similar to the September hydroacoustic estimate. If the herring in Area 14 and Areas 17 and 18 are different, then presumably some of the Area 14 herring could have entered from the north and so would not have been present on the west coast.

The March estimate would not be expected to agree with any of the independent estimates, as it should represent nonspawning fish. As has been pointed out, it actually consisted mainly of spent herring presumably from both the Strait of Georgia and west coast spawnings.

Very little is therefore gained by comparing the hydroacoustic estimates with existing independent estimates not only because of the unestimated errors associated with each, but also because of doubt about what segments of the estimates should be compared. The best that can be said is that the hydroacoustic estimates do not appear to be out of line and there appears no reason to doubt the veracity of the method. However, uncertainty about species composition and the proportion of the various herring stocks within the survey area may affect the application of the results.

2. Other Fish

(a) Offshore, West Coast of Vancouver Island

In addition to herring, 5 other species were frequently encountered on these surveys. These were hake, pollock, dogfish, yellowtail and redstriped rockfish.

(i) September

Hake and Pollock - In September 68,230 t of hake and 31,180 t of pollock (Table 8) were estimated to be present in the survey area. The hake

and pollock occurred mainly (84% and 92%, respectively) in a broad band running from the Cape Beale Spit around the Finger Bank, along the steep inner edge of the Prairie Grounds, to the central section of the Juan de Fuca Trench (Fig. 21). Other smaller concentrations occurred in Barkley Basin (9% for hake and 6% for pollock), and in the Juan de Fuca Trench off Swiftsure Bank (6%, 10%, respectively). No hake or pollock were found along the outer edge of the shelf among the herring schools.

Dogfish - Dogfish did not appear to be numerous in September (Table 8). Only 10,120 t were estimated to be present, 64% on or near Swiftsure Bank, 19% among the hake and pollock, and 11% along the outer edge of the shelf.

Rockfish - Hydroacoustic surveys will include any species of fish whose schools extend more than 3-5 m off the bottom. Midwater trawl catches to within this distance of the bottom show that 2 species of rockfish, the yellowtail and redstripe, may enter into the hydroacoustic estimates in certain areas. In September 4,645 t of yellowtail and 3,030 t of redstripe rockfish were estimated to be present (Table 8). Most (83%) of the yellowtail rockfish occurred in the same areas as the major hake and pollock concentrations, while 46% of the redstripe rockfish occurred along the 100-fm edge, 31% on the edge of the Cape Beale Basin and 10% on the edge of the Southwest Corner of La Pérouse Bank (Fig. 21).

(ii) November

Hake and Pollock - In November the amount of hake present had decreased by about 50% to 33,870 t (Table 9). This was probably the result of emigration southward. The amount of pollock had decreased slightly (by 20%) to 25,090 t. The largest concentration of both species was in the Cape Beale Basin and along the eastern edge of the Prairie Grounds (Fig. 23). In this area there were estimated to be 22,000 t of hake and 13,200 t of pollock. Another 5,990 t of hake and 3,590 t of pollock occurred south of the Cape Beale Spit, and 5,800 t of hake and 6,710 t of pollock in Barkley Basin.

Dogfish - In November the amount of dogfish had increased sharply from September to 33,455 t (Table 9). About two-thirds (20,800 t) occurred in the area of the large herring concentrations from Nitinat Canyon to the Finger Bank (Fig. 23). Another 3,810 t (12%) occurred on the southern Prairie Grounds. The concentration on Swiftsure Bank (5,370 t) was about the same size as in September.

Rockfish - The amount of yellowtail rockfish increased from about 4,645 t in September to 14,435 t in November (Table 9). The major concentration (8,540 t or 53%) was on the outer edge of the shelf from the Nitinat Canyon to the Juan de Fuca Trench (Fig. 23), another 2,290 t (15%) occurred off the Washington coast south of the trench. The amount of redstripe rockfish found was about the same (3,755 t) as in September (3,030 t). Most (2,710 t or 7%) occurred along the edge of the shelf north of the Nitinat Canyon.

(iii) March

Hake and Pollock - Concentrations of fish other than herring occurred south of the Finger Bank and along the eastern edge of the Prairies

to the Juan de Fuca Trench, and north to Swiftsure Bank (Fig. 25). Considerably larger concentrations occurred in the same general area on the two previous cruises and were predominantly hake and pollock. Midwater tows made in these localities in March failed to yield any hake and pollock in spite of the fact that echograms typical of a strong hake layer were obtained from concentrations in the Juan de Fuca Trench. Either the trawler failed to relocate the hake layer or it consisted of small forage fish such as eulachon or anchovy as the small catches made in the area suggested.

In March there were estimated to be about 7,120 t of pollock in Barkley Basin (Table 10), about the same amount as in November (6,710 t). No hake were found in this area at this season.

Dogfish - There were estimated to be about 38,590 t of dogfish in the survey area in March (Table 10), an increase of 15% from November. Most of the dogfish (30,020 t or 78%) were in the "other fish" concentrations in the Cape Beale Basin, along the eastern edge of the Prairie Ground and in the eastern part of the Juan de Fuca Trench (Fig. 25). Another 5,320 t was estimated to be on Swiftsure Bank, about the same amount as was found there in September and November. Only small amounts (less than 950 t) were found in the herring concentration along the outer edge of the shelf.

Rockfish - In March there were estimated to be about 37,530 t of yellowtail rockfish and 6,950 t of "other" rockfish present (Table 10). The latter was mainly widow rockfish. Only small quantities of redstripe rockfish were found, mainly in the northern part of the area. Most of the yellowtail rockfish (31,900 t or 82%) occurred in the Juan de Fuca Trench and along the eastern edge of the Prairie Grounds (Fig. 25). Another 3,230 t (9%) occurred in Barkley Basin. Only small catches of fish, out of proportion with the indicated density, were made from the unidentified concentrations from the Cape Beale Basin to the Juan de Fuca Trench. The catches made were predominantly yellowtail rockfish. It is from them that the large biomass estimate of this species stems. It has been pointed out that it is possible some concentrations of species of fish other than herring may not have been relocated by the fishing vessel, or a major component may have been forage fish which were not retained by the net. It is possible therefore that the yellowtail rockfish biomass in this area may have been well overestimated. Redstripe rockfish were scarce in March, but the semi-pelagic widow rockfish was more numerous than on other cruises.

(b) Barkley and Clayoquot Sounds

In March the deeper parts of Barkley and Clayoquot Sounds were found to contain a mixture of fish, mainly hake and dogfish, with some pollock and rockfish. In Barkley Sound there were estimated to be 553 t of hake and 708 t of dogfish, 74% in Imperial Eagle Channel, 24% in Trevor Channel and about 2% in Loudoun Channel. In Clayoquot Sound (Table 11) there were estimated to be about 219 t of hake in Tofino Inlet and Fortune Channel, while in Millar Channel and Herbert Inlet there were 234 t of hake, 24 t of dogfish, a small amount of rockfish and a trace of pollock. In Sydney Inlet 353 t of hake were estimated to be present. Rockfish occurred in scattered rocky localities throughout both sounds. A total of 33 t was estimated for Barkley Sound and about 10 t in Clayoquot Sound.

(c) Discussion

The quantity of hake declined sharply from 68,230 t in September to 33,870 t in November. In March this species did not enter the catches made offshore, although a typical hake-like layer was detected in the Juan de Fuca Trench during the hydroacoustic survey. In both September and November the main body of hake extended from the Cape Beale Basin, Finger Bank and along the eastern edge of the Prairies to the Juan de Fuca Trench. In Barkley Basin there was estimated to be about 6,000 t of hake in September and November but none were found there in March. Catches in nearby Trevor Channel showed the presence of hake in November and of reduced numbers in March. Catches also indicated hake were present in March in Millar Channel and Sydney Inlet.

It would appear that the main body of hake that was present in September had migrated out of the area by March, presumably south along the American coast. This movement was probably underway in November and accounts for the reduced biomass found then.

In September and November the quantity of pollock remained about the same (31,180 t in September and 25,090 t in November). In September most (27,800 t) were with the hake on the eastern edge of the Prairies, while in November the amount there had declined to 13,200 t. None was located there in March. The amount of pollock in Barkley Basin increased from about 1,920 t in September to over 6,700 t in November and March.

The quantity of dogfish increased from about 10,120 t in September to 33,455 t in November and to 38,590 t in March. In all 3 months about the same amount of dogfish (5,300 to 6,000 t) was found on Swiftsure Bank. In November a large body of dogfish (24,600 t) appeared on the outer edge of the shelf south of the Nitinat Canyon and in March had moved to the Finger Bank, the eastern edge of the Prairies and into the Juan de Fuca Trench.

The estimated biomass of yellowtail rockfish increased from 4,645 t in September to 14,435 t in November and apparently to 37,530 t in March. The increase in November occurred on the outer edge of the shelf south of the Nitinat Canyon. As previously mentioned the March biomass may have been well overestimated because of inadequate catch data from the fish concentration on the eastern edge of the Prairies and in the Juan de Fuca Trench. The quantity of redstripe rockfish was roughly constant in September and November (3,030 t and 3,755 t, respectively), although in November this species appeared more numerous on the outer edge of the shelf off Barkley Canyon. In March the only concentration found was off Estevan Point.

3. Reliability of Estimates

(a) Repeated and Comparative Surveys

In considering the reliability of hydroacoustic estimates--or indeed those of any method of estimation--the distinction between accuracy and precision must be appreciated. Accuracy is the distance the estimate obtained is from the real value. Precision is a measure of how closely a series of estimates are to each other. If there is no bias in the method, precision and accuracy are the same. Because of bias a method may yield precise but not necessarily accurate results. Statistical procedures estimate accuracy only

when it can be established that no bias exists in the measurements. If bias exists such procedures may estimate precision.

A series of hydroacoustic measurements of an area, made within a period of time short enough to minimize any effect of fish movement, will give some idea of the precision of the estimates but not of the accuracy. Similarity in estimates by 2 or more different methods should lead to increased confidence in them. For there to be similarity the biasses should either all be in the same direction or should be small--since each method is probably subject to different biasses the latter would seem perhaps to be a little more likely.

In September a selected area (Fig. 37) was surveyed on 3 separate occasions, the first as part of the regular survey, the second and third on consecutive days, 5 days later. At the same time trawl tows were made in this area at 13 randomly preselected sites. The purposes were to determine how repeatable biomass estimates from hydroacoustic surveys are, and to compare the hydroacoustic biomass estimates with an estimate derived from trawler catches. The area selected was that occupied by the major herring concentration off Nitinat Canyon. The first survey on September 16 was based on the original grid of track-lines. On the repeat surveys on September 21st and 22nd, additional track-lines were inserted equidistant between the original lines. The area covered was 561 km^2, and on the original survey contained 160 km of track-line, on the second 219 km and on the third 208 km. An estimate of relative density was obtained every nautical mile on all surveys.

The distribution maps (Fig. 37) show that between the original survey and the two repeat surveys the herring had moved more inshore and a little to the north. On the second and third surveys, distribution was generally similar, although some movement of schools, particularily in the northeast corner had occurred over the intervening 24 hours. On the first survey there was a considerable area of high density which was not present on the second and third surveys.

In making the biomass estimates, areas where no herring occurred were excluded. On the first cruise, herring were found over an area of 368 km^2, on the second of 374 km^2, and on the third of 370 km^2. On the first cruise there were estimated to be 27,400 t within the survey area, on the second 16,000 t, and on the third survey 11,000 t. Since the areas are so similar (within 1.6%) the differences in biomass must be related to difference in herring density. Using a "t" test, the null hypothesis that there is no difference in mean density between surveys is not rejected when comparing the second and third surveys but is rejected when comparing the first and second, and the first and third surveys, at the 5% and 1% levels, respectively. The 3 surveys show that repeatable results are obtained from hydroacoustic surveys provided the time between surveys is short, but that over a period of days, when the fish are migrating, the estimates may differ. On both of the repeat surveys a considerable amount of activity among the herring schools was observed in the northeast corner of the survey area. Some herring may have moved out of the area at this time and may explain the somewhat, but not significantly, lower estimate obtained on the third survey.

At the same time that the repeat surveys were being run, the accompanying trawler was making a series of randomly selected tows (Table 4; tows 38-50). The footrope was maintained 0-6 m off the bottom, and the mouth opening was 18 m. It was in this depth range that schools were most numerous. Two tows in this series were eliminated, one was outside the survey area, the other made 16 fm (29 m) off the bottom in an area where no fish schools were present. All the remaining tows consisted entirely of herring except one which contained 4% "other" fish. The catches (Table 12) were standardized to represent the catch over a fixed distance of 1.5 naut mi (2.78 km). These catches were used to provide an estimate of biomass to compare with the hydroacoustic estimates.

$$B_t = \frac{\bar{c}_b A_t d}{v\ k}\ (1+m)$$

where:

B_t = Biomass (t) in the survey area.
c_t = average catch (t), standardized to a fixed distance trawled of 1.5 naut mi, in the depth zone swept by the net.
A_t = total area of survey zone.
d = zone swept by net; it is 18 m.
v = volume swept by net in a standard tow. It is the product of the standard distance towed and the vertical and horizontal dimensions of the net. For the Egeland box trawl used, these dimensions were both 10 fm (18 m).
k = 1.0. It is assumed the net catches and retains all fish in its path.
m = The relative proportion of fish above the path of the net. This proportion was determined by measuring the width, height and position of schools from the echogram.

$$B_t = \frac{1471\ \text{kg} \times 371\ \text{km}^2 \times 18\ \text{m}\ (1 + .68)}{2.78\ \text{km} \times 18^2\ \text{m}^2 \times 1} = 18{,}322\ \text{t}.$$

The swept volume estimate is based on two assumptions which while usual to such a method and not unreasonable have not been substantiated. The first is that all the fish in the path of the net are retained by the net; none escape around or through it. The second is that the frontal area of the net is its effective fishing area and that in midwater trawls the otter boards and sweep lines have no herding effect as has been proposed for bottom trawls. These assumptions may bias the estimate. The catches also exhibited a high degree of variability. The relative variance of the catch was $\pm$44%, and the 95% confidence limits $\pm$98%. If our statistical analysis is appropriate, using the upper and lower 95% limits results in biomass estimates of 361 to 36,283 t.

Because some emigration may have occurred between the two repeat hydroacoustic surveys, the first and higher estimate (16,000 t) is perhaps the one that should be compared to the swept volume estimate. The hydroacoustic estimate is based on an average relative intensity of 2.1204×10^{-5} per printout interval of approximately 1 naut mi. The relative variance of the estimate is $\pm$18% and the 95% confidence limits $\pm$36%. Using these limits results in biomass estimates of 10,240 t to 21,760 t.

Both the hydroacoustic and swept volume methods resulted in generally similar biomass estimates. Both are subject to considerable variation but that associated with the hydroacoustic estimate is likely to be lower, for although both intensity and catch had ranges extending over 3 orders of magnitude, over five times as many data points were used in each hydroacoustic estimate as in the swept volume estimate. Both intensity and catch reflect the wide variation in the amount of fish that can occur from place to place.

In addition to the variation just discussed, both methods are subject to biasses which are difficult to estimate and arise from the assumptions underlying each method. It would appear that more information exists about the levels of those affecting the hydroacoustic estimate (target strength and calibration) than that affecting the swept volume estimate (effective frontal area and catchability).

(b) Relative Variance

Any method of making an estimate usually involves certain basic assumptions. Hydroacoustic biomass estimates are no exception. The basic assumptions are:

1. that calibration is accurate, and the system stable;

2. that the target strength values used accurately represent the actual in situ situation;

3. that the species composition for each concentration is known;

4. that all herring and other stocks of interest are fully "visible" to the sounder, and lie within the integrator's operating range;

5. that the whole of the stock is available for survey.

If these assumptions are considered to be met, then the accuracy of the estimates will be represented by the relative variance of the individual density estimates.

Although hydroacoustic measurements yield a large number of observations, whose analysis should yield a valid estimate of the variance, it has proved difficult to find a satisfactory model. One reason is that the vessel follows a predetermined regular grid of track-lines along which the observations are taken serially. A simple method based on the assumption of normal distribution has been used (Forbes and Nakken, 1972). The relative variances[8] obtained (Table 13, columns 3,6,9) were larger for herring concentrations than for hake and rockfish, and among herring concentrations were larger on the September and November cruises than on the March cruise. For herring, in September the values varied from 15.8 to 59.1%, in November from 9.5 to 74.7%, and in March from 12.8 to 45.4%. The size of the relative variance will be affected directly by the number of observations and by their range.

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[8] Standard error of the mean divided by the mean.

By reducing the number of observations included in each print-out to the point where each represents a single transmission, it is theoretically possible to increase the number of observations 300-fold. An increase of 2- or 3-fold might be tolerable with present computing methods. However, greater increases will depend on more refined methods of analysis based on recording data from each transmission. This, although technically possible, is not feasible with present equipment. Fish densities extend over a wide range, at least of 2 orders of magnitude, and where dense concentrations occur, of up to 4 orders of magnitude. Stratifying the observations would also reduce the variance. This approach has not been considered legitimate since by progressively reducing the stratum interval (contour interval in this case) the relative variance could be reduced until it approaches zero. As pointed out earlier the herring concentrations tended to be more widespread -- and hence contain more observations -- and less dense in March than in the other two months. The hake and rockfish concentrations on all 3 cruises were generally larger than the herring concentrations and of more even density. Shotton and Dowd (1975) have pointed out that this method may not be appropriate as neither the biomass distribution nor the sampling are normally or even randomly distributed. The estimated variance will be biassed low depending on the degree to which high and low values tend to be clustered together.

Consecutive echosounder transmissions may be correlated in the sense that they measure partially overlapping volumes of water as well as in the sense that if a high or a low value is found the chances are increased that the next value or values may also be high or low. Bayley and Hammersley (1948) provide a method of calculating the variance of such autocorrelated values which can be lagged by one to ten observations. This method has been used to calculate the relative variance of concentrations encountered on the March cruise (Table 13, column 12). The variance for positively correlated data would be expected from the formula to be somewhat larger than that for uncorrelated data. The estimates obtained however tend to be quite similar to those based on the assumption of random distribution.

Shotton and Dowd (1975) have proposed that the cluster analysis method of Hansen, Hurwitz, and Madow (1953) may be applicable. In this application of cluster analysis each transect is considered a cluster sample, and the average density target strength value per nautical mile the individual variable. Relative cluster analysis variances have been calculated for all fish concentrations encountered on the March cruise (Table 13, column 11). This method includes both within and between transect variation. The variance tends to be larger than that based on the assumption of random variation in most cases where there are more than 5 transects. However, where there are less than 5 transects the variance tends to be less than the "random" estimate and tends to become smaller the less transects there are. This method as now used may not be entirely applicable for:

1. it can be shown that the variance will become zero if the means of all transects are equal and based on the same number of observations. The chances of this occurring would be greater the fewer the number of transects.

2. the sampling fraction (the proportion that the area associated with each transect represents of the total concentration area) is assumed to be one.

3. all density values along each transect are used and are serially ordered rather than sampled.

(c) Sources of Error

The determination of the accuracy of an estimate should involve not only the estimation of variance but also of the extent to which the necessary basic assumptions are met. It is usually difficult to arrive at a quantitative estimate for four of these assumptions.

1. Calibration[9] in the last year has been satisfactory, and the new echosounder has proved to be very stable. The calibrations have involved the total sounder system, the transmitter-receiver, interconnecting and towing cables, and transducer. The results are given below; their constancy was apparently affected by a change in towing cable and the loss of a transducer (in November).

Sum of Transmit Level and Receiver Sensitivity			
Transceiver #1		Transceiver #2	
15/5/80	124.4dB	27/10/80	124.3dB
27/10/80	125.2dB	2/1/81	124.2dB
	125.5dB		

The results show that there has been no unaccounted variation in the performance of the equipment over the past year. The calibrations are considered accurate to $\pm$0.5dB[10], a quite acceptable value.

2. Target strength is the major "scaling" factor in hydroacoustic estimates and represents essentially how good a reflector of sound waves the fish is. It is a complex factor and depends on the length of the fish, its physical construction, especially the presence of a swim bladder, its swimming attitude in relation to the sounder, and its depth and perhaps depth accommodation history. We are unable to measure target strength in situ with our equipment. Such measurements require a second receiver and a special dual beam transducer. We rely therefore on selected target strengths taken from the literature. A subjective estimate suggests the effect on biomass estimates will be consistent from cruise to cruise but subject to a bias of $\pm$1 or perhaps 2dB. For herring the effect may be less. For this species we have used a value of -32 dB, rounded from a calculated value of -31.5 dB. Edwards

[8] Carried out by the Applied Physics Laboratory, University of Washington.

[9] A change of 1dB represents a change in biomass of 1.25 times.

(1980) obtained the same value (-31.5 dB) from measurements on tagged herring in Scotland. He also showed that the effect of changes in depth on herring target strength was unexpectedly small, especially in comparison to those for the physoclistous species.

3. The determination of the species composition of an area can be a major source of variability in hydroacoustic estimates. It is also an important source of error in any research vessel-based method of biomass estimation. Species composition is arrived at by a combination of net tows and echosounder record interpretation. Off the west coast of Vancouver Island the species conflicting with herring are hake and pollock, rockfish, dogfish, and eulachon. In most cases hake and pollock concentrations can probably be satisfactorily identified by fishing and from echograms. They usually occur over the deep water of channels, rather than on the edges of banks or of the shelf. Eulachon also can be separated with some assurance by the type of school in conjunction with the locality. They again tend to occur in the deep water of depressions and trenches. Rockfish and dogfish, for slightly different reasons, have proved the most difficult to separate from herring. Pelagic or semi-pelegic rockfish (especially the yellowtail and the redstripe) tend to be found in somewhat similar areas to herring and to form schools that in many cases are difficult to separate from herring schools from the appearance of the echosounder record. Dogfish produce echo returns that are very much weaker than those from fish with air bladders. On the basis of the method used for calculating target strength in this report, the signal from dogfish would be about 1/20-1/30 that from herring, for fish of the average size encountered. Returns from dogfish would become indistinguishable from noise at much shallower depths or at much higher concentrations than those from herring. Dogfish biomass is thus likely to be less reliably estimated than those of other species. While catches may show a certain proportion of dogfish to be present in an area, the echointegration values may or may not contain a component due to the species, depending on whether or not the signal returned from the dogfish exceeded the signal-to-noise ratio. The size of the returned signal would depend on the depth and the density of the dogfish. At certain seasons of the year dogfish are present in large enough numbers in areas frequented by herring so that separation of the two species from the appearance of the echosounder record can be difficult.

4. The assumption that all herring are fully "visible" to the sounder presumes that the school is not disturbed by the passage of the vessel. Olsen (1979, 1980, 1981) has shown that herring, especially when they are in a shallow layer at night, avoid the approach of a vessel. They first swim ahead of the vessel, and turn out of the path, and then as the vessel actually passes over them dive steeply. Both effects result in an underestimate of biomass. The first obviously decreases the number of fish in the path of the vessel, the second presents a tilted aspect to the sound beam and so results in a smaller signal. Avoidance reactions have been noted to occur over 50 m from the vessel. Avoidance may not be as serious a problem by day when the fish are in denser schools on or near the bottom in deep water.

5. The boundaries of the stock at any given season must be completely known. The result may be that although the area surveyed was adequately covered, some unknown part of the stocks may have lain outside the survey area. Emigration or immigration could also be occurring. The selection of the area and the time of the survey are thus critical factors.

In a previous section it was pointed out that herring were probably migrating out of the survey area in September, and may also have been in November. In March, herring were actively moving into the area from spawning grounds on the west coast and in the Strait of Georgia. In the case of the Strait of Georgia stock, there is some doubt about whether all the stock enters the Strait from the south--and so summers off the west coast--or whether some fish enter from the north via Johnstone Strait. It is also not clear that the distribution of pre-recruit herring is adequately known. There remains a possibility that all the non-maturing herring may not have been within the survey area. The estimation of the error from such sources requires either that pre-existing information be available or that information be collected from a wider area than that covered by the survey.

Considering all five factors it is possible that hydroacoustic estimates are accurate within a range of one-half to double. While this level of accuracy may seem low, it is probably no lower than the accuracies associated with other methods of estimating stock abundance. The precision of the estimates is much greater, probably in the range of 10-60% depending on the size of the concentration and the range of density within it.

The errors associated with method and equipment are probably at a reasonably acceptable level. However, those associated with biologically based variables (target strength, species composition and proportion of the stock "visible" to the sounder or within the survey area) remain of concern. These are difficult to estimate and could be substantial. The results obtained from the surveys were, however, consistent from cruise to cruise, explainable in terms of what is known about herring migration in the area, and do not differ substantially or unexplainably from those by existing methods.

D. BIOLOGICAL RESULTS

1. Herring - Age Composition

Herring samples were taken and frozen at sea. They were worked up and the ages determined under contract ashore. The use of contract samplers did not prove entirely satisfactory for trawl-caught herring. Because such herring are often badly descaled, considerably more care is required in taking the scale than is the case with seine-caught fish. A re-examination of 9 of 41 samples from the September cruise by an experienced staff scale reader resulted in from 8 to 25 (average 16) changes per sample in the ages determined. The most common causes were scales from the wrong fish, and inclusion of essentially unreadable scales. In one sample 22 changes were made in the ages of the first 75 fish, the remaining 25 fish had to be discarded because the scales were obviously out of order. In addition to the foregoing problems associated with the technique used, examination of the length frequency distribution of herring of ages 2 and 3 in September and

November (Fig. 38) suggests a possible additional source of error[11]. The curve of the length frequency distribution of age 3's shows a secondary peak falling immediately below the main peak for 2-yr-olds. Therefore either some age 3's remain so small that they essentially miss their second year's growth or some age 2's have been interpreted as 3-yr-olds. In September 8-10% of the 3-yr-olds may have been in this category, while in November the proportion was 20-25%. There is also an indication that some 3-yr-olds may have been interpreted as 2-yr-olds. The proportion, however, was much smaller. The same type of possible error may exist between other older age groups but because of the less obvious differences in size was not readily detected.

The percentage age composition of herring in each sample from the west coast of Vancouver Island in September, November, and March, and from the Strait of Georgia in November, is given in Tables 14-17. The samples are grouped according to area of herring concentration. In a number of cases, 2 or 3 samples were taken from a single haul. This was most often the case in the November west coast tows, and less frequently so for the September tows. No replicates were taken in March or in November in the Strait of Georgia. The age composition of the replicate samples was generally similar and usually showed the same age group dominance pattern. In only one set of samples (tow 38 in September) was there a major change. The difference was so large that the possibility cannot be overlooked that one sample was mislabelled.

On the west coast in all 3 months, there were several patterns of age group dominance (Tables 14-16). In some samples, 2-yr-olds predominated and in a few 3-yr-olds. In others, 2- and 3-yr-olds were dominant, in others 3- and 4-yr-olds, and in still others 4-, 5- and 6-yr-olds. These patterns were not confined to particular areas or concentrations, although there may have been a tendency for fish north of Amphitrite Point in the autumn to be mainly 2-yr-olds. Large concentrations usually contained examples of all patterns of age composition. It would appear that while herring may school to some extent by age, the age groups are not segregated by area. It is difficult therefore to establish a meaningful average age composition for such concentrations. There are no differences in the pattern of age composition with area in September or November that would indicate any trends. Differences occurred, but could have been as much random between sample or between school differences as differences associated with differential movement of age groups.

In the Strait of Georgia in November (Table 17), 3-yr-olds were the dominant age group off Victoria. In the Satellite Channel-Swanson Channel area this age group predominated in Plumper Sound, in Swanson Channel, 3- and 4-yr-olds did, while off Active Pass, 4-yr-olds were dominant. In Navy Channel 1-yr-olds were the main group, and in Satellite Channel, 1- and 2-yr-olds. In Trincomali Channel, 3- and 4-yr-olds predominated as they did in the Yellow Point area of Stuart Channel and in Sansum Narrows. However, off Crofton the herring were mainly 1-yr-olds.

An outstanding feature of the age composition in both September and November on the west coast was the practically complete absence of 1-yr-olds, the fish of the year. Only 2 samples, both in November, had fish that were

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[11] An age 2 herring shows one complete winter rings on the scale, and most probably some additional growth outside the last ring.

undisputably fish of the year and then only 1 or 2 individuals. The 1-yr-olds shown in September (Table 14) appear from their average length to be more probably 2-yr-olds. In other years 1-yr-olds have been found offshore as early as July. While the catch of this age group would not be expected to be proportional to abundance, it would be indicative of the presence of this age group on the grounds. The 1980 year-class may therefore be weak.

2. Herring - Maturity at Age

In March, the herring in the offshore samples were either fish that had not matured, and presumably would not do so this season (Table 18, maturity stages 1,2), or had spawned (maturity stages 7,8). There were only a few scattered ripe but unspawned fish (maturity stage 5). When the maturity composition by age group was examined it was found that all fish age 5 and over were mature (i.e. had spawned). Among age 4 fish, less than 1% (1 fish in 290 examined) was immature, while among age 3 herring about 1% (7 fish out of 525) were immature. Among age 2 fish, however, 34% were immature (105 fish out of 305). The percent of age 2's immature varied widely from sample to sample. Among samples with over 10 2-yr-olds, the percentage immature varied from 5 to 75%. About 90% of the immature age 2's were in maturity stage 1. As in the older fish, the 2-yr-olds that had matured had spawned and were in stage 7 or 8.

The samples obtained during the offshore cruises off the west coast confirm that there is a segment of the herring population that will not spawn in the current season. An examination of the age-maturity composition shows that this segment is made up of fish of age 2 and younger (although very few 1-yr-old herring were contained in the 1980-81 offshore samples). Among the 2-yr-olds about 66% were mature. This could be an underestimate as spent herring were still migrating offshore at the time of sampling, and all spawned 2-yr-old fish may not have been present on the grounds. Among older age groups only scattered immature individuals (1% or less) were found.

In March an examination of the stage of maturity in relation to length of fish expected to be age 2 revealed that most fish in maturity stage 1, i.e. fish that had never spawned, were smaller than the fish that had spawned.

IV. CONCLUSIONS

The relative abundance of fish beneath the ship can be estimated well by hydroacoustic methods. Accuracy will depend primarily on the calibration and on the inherent stability of the system. The equipment now in use has proved to be highly stable. Calibration is considered accurate to $\pm$ 0.5 dB.

The major factors affecting the accuracy of offshore hydroacoustic estimates are the validity of the target strength determinations, the estimation of species composition within the area, and the determination of

the proportion of the stock within the survey area. Target strength is the major "scaling" factor in arriving at an estimate of absolute abundance. At present in situ estimates are not possible with our equipment. Calculations derived from the literature are used. A subjective estimate suggests the effect on biomass will be consistent from cruise to cruise but subject to a bias of $\pm$ 1 or perhaps 2 dB. The species composition of large concentrations of only one or two species fished on a number of occasions is probably reasonably well estimated. For small concentrations not frequently fished, especially those containing a number of different species, the species composition may not be as reliable. The proportion of the stock within the survey area cannot be determined from the data collected on the cruises. While most of the large concentrations of herring were within the survey area, some herring occurred in the boundary regions especially along the outer boundary and in the Swiftsure Bank/Juan de Fuca Strait area. It is possible then other concentrations could have been outside the survey area.

The comparison of the hydroacoustic estimate with independent estimates, even those traditionally used by management, does little to establish the validity of any estimate unless the associated errors of one have been well established. Hydroacoustic estimates appear to agree reasonably well with estimates from traditional methods when migration is at a minimum and difficulties concerning the stock units to be included are resolvable.

The hydroacoustic estimates obtained were consistent from cruise to cruise and were explainable in terms of what is known about herring migration in the area. In a test area, hydroacoustic estimates were also shown to be repeatable, at least over a short period of time (24 h) when migration was not a serious factor. In the same area, an estimate based on catch and volume of water swept was approximately the same size as the hydroacoustic estimate but had very much wider confidence limits.

Future surveys of herring abundance should be aimed at establishing definitely the boundaries of herring distribution, especially offshore, and should occur at a time when all the stock is likely to be included in the survey area. Late January or early February may be the most suitable time.

It is important to know to what spawning stocks the west coast offshore herring contributed. This information is important not only for management but also for determining the composition of any spawn survey data based estimate to which the hydroacoustic estimate may be compared. During these cruises it was demonstrated that herring can be tagged offshore from midwater trawl tows provided the fish are not concentrated in the codend, and that the weather is relatively calm.

While herring may school to some extent by age offshore, as shown by the fact that samples from the major herring concentrations may show several patterns of age composition, the age groups are not segregated by area. It is difficult to establish therefore a meaningful average age composition for such concentrations. A noticeable feature of the age composition in both September and November on the west coast was the almost complete absence of 1-yr-olds, the fish of the year. The 1980 year-class may therefore be weak.

No large concentrations of 1- or 2-yr-old herring were found. The possibility exists either that these pre-recruit age groups occurred somewhere outside the survey area or that they were not as numerous as would be expected in comparison to other age groups.

Most of the 3-yr-old and older herring in the March samples were mature (in maturity stage 2 or 8). Among 2-yr-olds, 66% were mature. However, this percentage varied widely from sample to sample from 25 to 95%.

V. SUMMARY

1. The hydroacoustic surveys extended from the Juan de Fuca Trench north to Estevan Point, and were from Sept. 9-26, 1980 (GBR80-7), Nov. 3-21, 1980 (GBR80-3), and March 9-27, 1981 (GBR81-3). Fishing surveys were carried out at the same time by the OCEAN KING in September, the HOWE BAY in November, and the MARWOOD in March.

2. Concurrently with the offshore surveys, combined fishing-hydroacoustic surveys were carried out in November in the Strait of Georgia by the EASTWARD HO, and in March in Barkley and Clayoquot Sounds by the HOWE BAY.

3. In September the OCEAN KING made 61 midwater trawl tows usually of 30-min. duration with an Egeland box trawl.

(a) Most of the tows were made in the major herring concentrations along the outer edge of the continental shelf. Catches varied from 0 to 7,203 kg in tows of 15 to 50 min. A smaller number of tows were made on inshore grounds (La Pérouse and Swiftsure Banks). Catches varied from a trace to 7,665 kg of herring in tows of 15 to 30 min.

(b) There were 12 tows made in the main hake and pollock concentration. Catches of hake varied from less than 10 kg in a 30 min. tow to 4,433 kg in a 1 min. tow. Pollock catches were smaller and varied from 0 to 352 kg.

(c) In September, dogfish and rockfish catches were not large. Of the former, the largest catch was 1,438 kg in a 25-min. tow on Swiftsure Bank. Of the latter, the largest catch was 1,730 kg in a 3-min. tow on the Cape Beale Spit.

4. The OCEAN KING tagged 2,914 herring in 3 taggings on the outer edge of the continental shelf near the Nitinat Canyon. Three recoveries were made, 1 from Nootka Sound, 1 from Clayoquot Sound, and 1 with no recovery information. Recoveries were comparable to those from seine-caught fish and demonstrate that trawl-caught fish can be tagged successfully.

5. In November the HOWE BAY made 42 midwater tows, usually of 30-min duration using an Orcutt box trawl.

(a) Most tows (27) were again made in the major herring concentrations along the outer edge of the shelf. Catches varied from 0 to 18,832 kg in tows of 5 to 30 min. In La Pérouse and Swiftsure Banks herring catches varied from 5 to 5,136 kg in tows of 15 to 30 min.

(b) Six tows were made in the hake and pollock concentrations in Barkley Basin and along the eastern edge of the Prairie Ground. Hake catches were small, less than 300 kg per 30-min tow. Pollock catches were larger, from 48 to over 800 kg per 30-min. tow.

(c) Dogfish catches were larger than in September. Catches of up to 1,015 kg in a 30-min tow were made in the herring concentrations along the outer edge of the shelf. Rockfish catches were also larger, especially of the redstripe. The largest catch was 763 kg in a 5-min. tow off Barkley Canyon.

6. In March, the MARWOOD made 27 midwater trawl tows, the G.B REED 14 and the HOWE BAY 19. The nets used depended on the vessel (Table 2).

(a) Herring catches were smaller than on the September and November cruises. On the outer edge of the shelf catches carried from 0 to 262 kg in tows of 8 to 85 min. The largest catch of 660 kg in a 50-min tow was made on Swiftsure Bank.

(b) No hake were caught offshore, although catches of 342 to 1,892 kg in tows of 8 to 17 min. were made in Sydney Inlet and Millar Channel. Several catches of pollock were made offshore; the largest was 222 kg in a 30-min. tow in Barkley Basin.

(c) Dogfish were numerous on the inshore grounds. A catch of 18,000 kg in 85 min. was made on the Finger Bank, and another of 23,000 kg in 13 min. in the Cape Beale Basin.

7. In the Strait of Georgia the EASTWARD HO made 23 midwater trawl tows, mainly in herring concentrations. The largest herring catches were made off Victoria (829 kg in 13 min.), off Active Pass (2,040 kg in 89 min.), off Yellow Point (1,649 kg in 14 min.) and in Deepwater Bay (627 kg in 6 min). Pollock were caught off Victoria, Lund, and in Jervis Inlet.

8. In September there were estimated to be 67,740 t of herring from the Juan de Fuca Trench to Estevan Point, with only 5,630 t found north of Amphitrite Point. There were estimated to be 48,990 t along the outer edge of the continental shelf, 31,030 t south of the U.S.-Canada fishing boundary. Smaller concentrations were found on La Pérouse Bank (6,260 t), and on Swiftsure Bank (2,720 t). An additional 10,480 t were located outside the survey area off Victoria.

9. In November, 53,700 t of herring were estimated to be on the offshore grounds with only 2,900 t occurring north of Amphitrite Point. Most of the herring (39,610 t) were still along the outer edge of the shelf, but only 12,370 t were south of the U.S.-Canada fishing boundary. The largest concentration of 23,900 t was north of the Nitinat Canyon. On La Pérouse Bank 3,250 t were located, and in the Swiftsure Bank area 9,110 t.

10. In March only 33,465 t of herring were found offshore. The herring were more widely distributed. There were 5,310 t south of the U.S.-Canada boundary, 6,550 t north of the boundary to Amphitrite and 5,775 t north of Amphitrite Point. The largest concentration was on Swiftsure Bank (12,300 t). Unfortunately the Barkley and Clayoquot Sounds survey was carried out after

most of the spawning had occurred. Only small amounts of herring remained inshore.

11. The November biomass estimate of 53,700 t compared reasonably well with estimates from catch, sampling, and spawn deposition data and from the pre-fishery echosounder surveys (57,200 t and 46,700-48,600 t, respectively). The September estimate was low. The basis of comparison was difficult to determine; emigration may have reduced the quantity of Strait of Georgia herring off the west coast at the time of the survey, and there was doubt about the proportion of Strait of Georgia fish summering off the west coast. In March no comparison was possible, herring were actively migrating offshore.

12. Hake and Pollock

(a) In September there were estimated to be 68,230 t of hake and 31,880 t of pollock in the survey area. The concentration lay in a broad band from the Cape Beale Spit around the Finger Bank, along the eastern edge of the Prairie Ground and into the Juan de Fuca Trench. Smaller concentrations were found in Barkley Basin and near Swiftsure Bank.

(b) In November the biomass of hake had declined to 33,870 t and of pollock to 25,090 t. While 22,000 t of hake and 13,200 t of pollock were found in the same area as in September, 5,990 t of hake and 3,590 t of pollock occurred near the mouth of the Juan de Fuca Trench, and 5,800 t of hake and 6,710 t of pollock in Barkley Basin.

(c) In March no hake were located offshore, although small amounts were caught in Trevor Channel and in Clayoquot Sound. In Barkley Basin 7,120 t of pollock were present.

13. Dogfish

(a) In September only 10,120 t of dogfish were found, mainly on Swiftsure Bank (6,060 t), or among the hake and pollock.

(b) In November the quantity of dogfish had increased to 33,455 t, about two-thirds in the area of the large herring concentration from Nitinat Canyon to the Finger Bank. The amount on Swiftsure Bank was about the same in September.

(c) In March the dogfish stock was estimated to be 38,590 t. Of this 30,020 t were found from the Cape Beale Basin along the eastern edge of the Prairies to the Juan de Fuca Trench. There were 5,320 t on Swiftsure Bank.

14. Rockfish

(a) In September 4,645 t of yellowtail and 3,030 t of redstripe were estimated to be present. The yellowtail occurred in the same area as the hake and pollock, the redstripe along the 100-fm edge.

(b) In November, the amount of yellowtail rockfish had increased to 14,435 t with the appearance of a concentration on the edge of the shelf south of the Nitinat Canyon. The amount of redstripe rockfish (3,755 t) was about the same as in September.

(c) In March, the estimate of yellowtail rockfish was 37,530 t, which, for the reasons given, was probably considerably too large. Redstripe rockfish appeared scarce. Other rockfish were more numerous; for example, 2,870 t of widow rockfish were estimated to be present on Swiftsure Bank.

15. In September, 3 estimates of the biomass of herring in a section of the main concentration were made, the second and third estimates a day apart, 5 and 6 days after the original. At the same time and in the same area, a swept volume estimate based on 13 trawl tows was made. The hydroacoustic estimates were 27,400 t, 16,000 t, and 11,000 t. The second and third estimates are not significantly different statistically but the first and second, and first and third are. It would appear herring had moved out of the area in the 5 days following the first survey. The swept volume estimate was 18,300 t, with 95% confidence limits of 361-36,283 t. Similar limits on the second hydroacoustic estimate were 10,240-21,760 t. Considering the biases associated with both estimates, but particularly with the swept volume estimate, the results cannot be considered to disagree widely.

16. The relative variance of the herring biomass estimates varied from 15.8 to 59.1% in September, 9.8 to 74.7% in November, and 12.8 to 45.4% in March. The size of the relative variances will be affected directly by the number of observations and their range.

17. The accuracy of the hydroacoustic estimates depends on the extent to which 5 basic assumptions are met: (1) that calibration is accurate and the equipment stable; (2) that target strength values used are good estimates of the actual in situ values; (3) that the species composition of an area is reasonably determined; (4) that all herring are fully "visible" to the sounder; and (5) that the boundaries of the stock are within the survey area.

18. While herring offshore may school to some extent by age, the age groups are not segregated by area. In some samples 2-yr-olds predominated, in others 2- and 3-yr-olds, in others 3- and 4-yr-olds and still others 4-, 5- and 6-yr-olds. In contrast to surveys in other years no age 1 herring were caught.

19. In March, among fish age 3 and older, 1% or less were immature. However, among 2-yr-olds 34% were immature, apparently the smaller members of this age group. Very few 1-yr-olds were found.

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Table 1. Average percentage species composition of major fish concentrations on the September and November, 1980, and March, 1981, offshore herring cruises.

Area	Percentage								
	Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
September									
Herring concentrations									
Outer edge-Loudoun Canyon	75	-	-	-	25	-	-	-	-
Outer edge-Barkley Canyon	46	15	-	-	1	1	33	-	5
Outer edge-Barkley Canyon-South	93	-	+	-	1	1	5	-	-
Outer edge-Nitinat Canyon	99	-	+	-	-	-	+	-	-
Outer edge-South Prairies	82	-	-	-	-	-	5	13	+
Southwest Corner	84	-	-	-	-	1	14	-	1
Swiftsure Bank	31	-	-	-	69	-	-	-	-
Central Prairies	98	-	-	-	-	1	-	-	1
Other fish concentrations									
Barkley Basin	-	-	72	13	1	-	-	-	14
Cape Beale Basin	19	-	80	-	-	-	-	1	-
Eastern edge-Prairies	+	-	53	39	2	5	-	+	-
Swiftsure Spit	-	-	94	5	-	1	-	-	-
Central Prairies	6	-	34	12	19	15	14	-	-
Cape Beale Spit	-	-	-	-	-	2	75	22	1
Finger Bank	-	-	-	-	4	96	-	-	-
November									
Herring concentrations									
Outer edge-Nitinat Canyon	48	+	-	3	42	6	+	+	-
Outer edge-South Prairies	62	-	-	-	37	-	2	-	-
Central Prairies	54	-	-	-	39	-	3	1	3
Finger Bank & Southeast Corner	84	-	-	-	3	13	-	-	-
Swiftsure Bank	50	-	-	-	34	-	1	-	15
Washington Coast	42	-	1	-	2	31	-	23	-
Other fish concentrations									
Barkley Basin	-	2	39	45	2	8	3	1	1
Central Prairies	-	-	60	36	2	2	-	-	-
Prairies-east edge	-	-	-	-	8	-	92	1	-
Barkley Canyon	-	-	-	-	-	13	86	+	1

Table 1 (cont'd)

Area	Percentage								
	Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
March									
Herring concentrations									
Off Estevan Point	50	-	-	-	-	3	47	-	-
Outer edge-Loudoun Canyon	89	4	-	-	3	4	-	-	-
Outer edge-Barkley/Nitinat Canyons	75	-	-	-	1	5	-	19	-
Outer edge-South Prairies	79	-	-	-	14	-	1	4	2
Southeast Corner	92	-	-	-	8	-	-	-	-
Central Prairies	77	23	-	-	-	-	-	-	-
Swiftsure Bank	60	-	-	-	26	-	-	14	+
Swiftsure Spit	100	-	-	-	-	-	-	-	-
Other fish concentrations									
Barkley Basin	+	1	-	53	5	24	-	6	10
Prairies-east edge	1	3	-	56	-	33	-	4	3
Juan de Fuca Trench	-	5	-	-	30	58	-	-	7
Finger Bank East	-	-	-	-	-	100	-	-	-
Southwest Corner	-	-	-	-	-	100	-	-	-
Cape Beale Basin	-	-	-	-	100	-	-	-	-
Central Prairies	-	-	-	-	-	-	-	100	-
Port San Juan	7	6	-	15	26	4	-	-	41
Strait of Georgia									
Victoria	97	-	-	3	+	-	-	-	-
Swanson Channel	98	-	-	2	-	-	-	-	-
Satellite Channel	82	-	-	18	-	-	-	-	-
Plumper Sound	79	-	8	8	4	-	-	-	-
Active Pass	100	-	-	-	-	-	-	-	-
Trincomali Channel	99	-	1	-	1	-	-	-	-
Crofton Sansum Narrows	14	-	35	+	51	-	-	-	-
Yellow Point	88	-	+	-	12	-	-	-	-
Deepwater Bay	73	-	-	+	27	-	-	-	-
Lund	-	-	30	62	8	-	-	-	-
Jervis Inlet	-	-	15	83	1	-	-	-	-

Table 1 (cont'd)

Area	Percentage								
	Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Barkley and Clayoquot Sounds									
March									
Sydney Inlet	-	-	100	-	-	+	-	-	-
Tofino Inlet	-	-	100	-	-	-	-	-	-
Millar Channel	-	-	99	+	-	1	-	-	-
Millar Channel	-	-	74	1	18	5	-	1	1
Trevor Channel	-	-	44	-	56	-	-	-	-

Table 2. Details of vessels, fishing equipment and nets used on the September and November, 1980, and March, 1981, offshore herring cruises.

Vessel	G.B. REED	OCEAN KING	HOWE BAY	EASTWARD HO	CARWOOD
Length	176' 54 m	96' 29 m	92' 28 m	108' 33 m	128' 39 m
Horsepower	1000	725	674	800	750
Otter boards	$3m^2$ Süberkrüb	V door	$5m^2$ Süberkrüb	$5m^2$ Süberkrüb	Süberkrüb
Sweepline length (fm)	40 fm	40 fm	35 fm	?	50 fm
Trawl type	434 Engel	Egeland Box	Orcutt Box	Can. Diamond 7	Can. Diamond 8
Average Mouth Opening (m)	11 m	18 m	15 m	12 m	17 m
1st body mesh size (in)	16	48	32	32	22
4th body mesh size	--	3	4	4 3/4	4 1/2
Codend mesh	1 1/2 double mesh	1 1/2	1 1/4	1 1/2	3 1/2
Liner mesh size	1.0"	1.0"	1.0"	1.0"	1 1/4
Netsounder	Elac. cable	Furuno 400 cabless	Furuno cabless	Kelven- Hughes cable	Furuno cabless
Ships sounder	Simrad ER38	FNV 450 50 & 200kHz	Simrad	Ekolite	Simrad

Table 3. Common and scientific names of all species encountered on the September and November, 1980, and March, 1981, herring cruises.

Common Name	Scientific Name
Soupfin shark	Galeorhinus zyopterus
Spiny dogfish	Squalus acanthias
Big skate	Raja binoculata
Ratfish	Hydrolagus colliei
American Shad	Alosa sapidissima
Pacific herring	Clupea harengus pallasi
Northern anchovy	Engraulis mordax mordax
Coho salmon	Oncorhynchus kisutch
Chinook salmon	Oncorhychus tschawytscha
Eulachon	Thaleichthys pacificus
Eared blacksmelt	Bathylagus ochotensis
Northern smoothtongue	Leuroglossus stilbius schmidti
Ribbon barracudina	Notolepis rissoi rissoi
Calfornia headlightfish	Diaphus theta
Pacific cod	Gadus macrocephalus
Pacific hake	Merluccius productus
Pacific tomcod	Microgadus proximus
Walleye pollock	Theragra chalrogramma
Eelpout	Zoarcidae
King-of-the-salmon	Trachipterus altivelis
Chub mackerel	Scomber japonicus
Medusafish	Icichthys lockingtoni
Silvergray rockfish	Sebastes brevispinis
Widow rockfish	Sebastes entomelas
Yellowtail rockfish	Sebastes flavidus
Bocaccio	Sebastes paucispinis
Canary rockfish	Sebastes pinniger
Redstripe rockfish	Sebastes proriger
Pygmy rockfish	Sebastes wilsoni
Sablefish	Anoplopoma fimbria
Lingcod	Ophiodon elongatus
Arrowtooth flounder (turbot)	Atheresthes stomias
Rex sole	Glyptocephalus zachirus
Flathead sole	Hippoglossoides elassodon
Rock sole	Lepidopsetta bilineata
Dover sole	Microstomus pacificus
English sole	Parophrys vetulus

Table 4. Catch by species, by the OCEAN KING from the major fish concentrations on the west coast of Vancouver Island, Sept. 9-26, 1980.

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Outer edge, Loudoun Canyon	22	675	30	1350	675	-	-	-	-	-	-	-	-
	24	76	30	151	38	-	-	-	38	-	-	-	+
Outer edge, Barkley Canyon	21	92	29	190	87	-	-	-	-	3	2		
	25	27	26	62	2	-	-	-	1	-	20	-	4
	26	11	31	21	2	-	-	-	-	-	10		
	56	893	30	1786	881	-	-	-	-	-	6	-	6
	57	55	30	111	8	42	-	-	1	-	-	-	4
Outer edge, Barkley Canyon South	11	773	30	1446	695	-	6	-	-	15	54	-	2
	20	0	30	0	-	-	-	-	-	-	-	-	-
	52	4	30	16	1	-	-	-	3	-	-	-	-
	53	1716	30	3432	1662	-	-	-	35	8	10	-	-
	54	1511	30	3022	1300	-	-	-	35	28	145	4	-
	55	30	40	45	30	-	-	-	-	-	-	-	-
Outer edge, Nitinat Canyon South	6	842	30	1684	842	-	-	-	-	-	-	-	-
	7	2077	15	8307	2077	-	-	-	-	-	-	-	-
	8	1092	30	2183	1092	-	-	-	-	-	-	-	-
	10	261	26	603	258	-	2	-	-	-	-	-	+
	31	7273	15	29092	7203	-	-	-	-	25	-	45	-
	33	4	31	8	4	-	-	-	-	-	-	+	-
	37	0	49	0	-	-	-	-	-	-	-	-	-
	38	114	30	228	114	-	-	-	-	-	-	-	-
	39	2729	30	5458	2727	-	-	-	-	2	-	-	-

Table 4 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Outer edge, Nitinat Canyon South	40	37	30	74	37	-	-	-	-	-	-	-	-
	41	6364	30	12728	6364	-	-	-	-	-	-	-	-
	42	2500	30	5000	2497	-	-	-	3	-	-	-	-
	43	348	30	698	348	-	-	-	-	-	-	-	-
	49	136	30	272	130	-	4	-	-	-	1	-	-
	45	32	30	64	32	-	-	-	-	-	-	-	-
	46	457	30	914	454	-	-	-	-	-	-	-	3
	47	0	30	0	-	-	-	-	-	-	-	-	-
	48	0	30	0	-	-	-	-	-	-	-	-	-
	49	77	30	154	74	-	3	-	-	-	-	-	-
	50	2727	60	2727	2727	-	-	-	-	-	-	-	-
Outer edge, South Prairies	29	666	30	1332	581	-	-	-	1	-	-	78	6
	30	38	30	75	29	-	-	-	-	-	4	5	-
	34	+	30	+	+	-	-	-	-	-	-	-	-
Washington coast	35	0	30	0	-	-	-	-	-	-	-	-	-
Southwest Corner	27	1125	30	2250	600	-	-	-	-	18	476	-	31
	58	+	30	1	+	-	-	-	-	-	-	-	-
	59	1602	30	3205	1590	-	-	-	-	-	-	-	12
Swiftsure Bank	1	148	15	590	6	-	-	-	142	-	-	-	-
	2	241	30	483	14	-	-	-	228	-	-	-	-
	3	9110	25	21863	7665	-	-	-	1438	2	-	-	4

Table 4 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Central Prairies	12	338	30	676	332	-	-	-	-	4	-	-	2
Barkley Basin	17	12	30	23	-	-	9	-	-	-	-	-	3
	28	329	30	658	+	-	235	87	6	-	-	-	1
Cape Beale Basin	19	1001	30	2022	389	-	619	-	-	-	-	-	4
	60	4546	1	272730	-	-	4433	-	-	91	-	20	1
East edge, Prairies	5	1340	34	2365	-	-	1038	294	8	-	-	-	-
	13	19	30	38	-	-	2	15	-	2	-	-	-
	14	35	30	70	-	-	10	25	-	-	-	-	-
	16	443	30	886	-	-	396	-	38	8	-	-	1
	32	670	30	1340	-	1	669	-	-	-	-	-	-
	36	139	37	225	+	-	94	-	8	36	-	1	-
	61	352	30	704	-	-	-	352	-	-	-	-	-
Swiftsure Spit	4	2609	30	5218	-	-	2456	127	6	20	-	-	-
Prairies	9	15	30	30	2	-	5	-	2	2	4	-	-
	51	64	30	128	+	+	22	15	16	10	+	-	-
Cape Beale Spit	18	2307	30	4614	-	-	-	-	3	57	1730	510	8
Finger Bank	15	136	42	194	-	-	-	-	6	130	-	-	-
Contintental Slope	23	0	30	0	-	-	-	-	-	-	-	-	-

Table 5. Catch by species by the HOWE BAY from the major fish concentrations on the west coast of Vancouver Island, Nov. 3-21, 1980.

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Outer edge, Loudoun Canyon	31	4	30	8	-	-	-	-	-	2	1	-	1
Outer edge, Barkley Canyon	29	832	5	9984	-	-	-	-	63	-	763	6	-
	30	118	30	236	-	-	-	-	-	12	107	-	-
	33	555	30	1110	-	-	-	-	-	178	360	5	12
	34	63	30	126	-	-	-	-	-	10	53	-	-
	35	818	30	1636	1	-	-	3	+	3	806	-	5
	40	48	30	96	+	+	-	-	26	2	4	-	16
Outer edge, Nitinat Canyon	16	609	30	1218	-	-	-	-	605	4	-	-	-
	17	864	5	10368	673	-	-	-	191	-	-	-	-
	18	8909	25	21382	8346	-	-	-	536	14	10	-	1
	19	19218	15	76872	18832	-	-	1	364	-	-	-	12
	20	237	30	474	12	3	-	12	198	12	-	-	-
	28	28	10	165	18	+	-	+	-	+	+	-	10
	36	258	30	516	7	4	-	4	217	19	8	-	-
	37	1318	30	2636	10	-	-	-	1015	293	-	-	-
	38	366	30	732	8	7	-	86	167	81	+	14	3
Central Prairies	27	236	30	472	128	-	-	-	92	-	8	2	7
Outer edge, South Prairies	12	1591	30	3182	677	-	-	-	906	-	3	+	6
	13	1364	30	2728	1095	+	-	2	224	6	38	-	-
	14	25	30	50	2	-	-	-	21	3	-	-	-

Table 5 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Outer edge, South Prairies	11	477	20	1431	-	-	-	-	462	-	-	-	14
	8	1045	30	2090	-	-	-	-	25	510	-	510	-
	15	1908	30	3816	-	-	-	-	-	1760	-	148	-
Washington coast	9	318	20	954	134	-	2	-	6	100	-	74	1
	10	+	30	+	-	-	-	-	-	-	-	-	-
Southwest Corner	41	22	30	44	5	5	-	2	-	-	-	-	10
Finger Bank	21	727	15	2908	510	-	-	-	24	190	-	-	2
	4	5636	20	16908	5136	-	-	-	-	-	-	-	-
	24	2500	25	6000	2436	-	-	-	60	-	-	-	3
	23	1068	5	12816	1037	-	-	-	37	-	-	+	4
	25	24	20	72	5	-	-	-	-	10	6	-	3
Swiftsure Bank	1	273	20	819	250	-	-	-	23	-	-	-	-
	2	318	30	636	25	-	-	-	192	6	-	-	94
Barkley Basin	22	217	30	434	+	14	144	48	-	6	-	-	4
	32	482	25	2830	-	-	293	815	4	6	62	1	-
	42	760	30	1520	-	-	182	338	41	158	22	16	2
Prairies, east edge	5	209	15	836	-	-	89	112	-	8	-	-	-
	39	286	30	572	-	-	222	49	16	-	+	-	-

Table 5 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Prairies, east edge	6	20	30	40	-	-	-	-	-	8	-	-	11
	7	35	30	70	13	-	-	-	-	20	-	-	2
Central Prairies	26	0	10	0	-	-	-	-	-	-	-	-	-
Trevor Channel	3	2704	20	8112	+	-	2518	128	50	2	-	6	-

Table 6. Catch by species by the G.B. REED, MARWOOD, and HOWE BAY from the major fish concentrations on the west coast of Vancouver Island, March 9-27, 1981.

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Father Charles Canyon	R1	157	31	304	78	-	-	-	-	5	74	-	-
	R2	0	8	0	-	-	-	-	-	-	-	-	-
	R3	15	30	30	11	2	-	-	-	2	-	-	-
	R4	+	30	+	+	+	-	-	-	-	-	-	-
Loudoun Canyon	R5	41	37	66	37	-	-	-	2	-	-	-	-
	R6	275	40	413	262	-	-	-	4	-	-	-	9
	M10	6	120	3	+	+	-	-	-	-	-	1	5
Outer edge, Barkley/Nitinat Canyons	R7	193	25	463	193	-	-	-	-	-	-	-	-
	R8	342	42	489	245	-	-	-	-	12	8	77	-
	H15	28	33	51	28	+	-	-	+	-	-	-	-
	H16	8	23	21	6	-	-	-	-	2	-	-	-
	M5	298	85	210	-	-	-	-	10	8	-	280	-
	M6	22	80	16	-	-	-	-	-	-	-	17	5
	M14	7	60	7	2	+	-	-	-	-	-	-	5
Outer edge, South Prairies	R10	51	30	102	51	-	-	-	-	-	-	-	-
	R11	46	33	84	37	-	-	-	8	-		-	+
	R12	68	38	107	31	-	-	-	37	-	-	-	-
	R13	150	30	300	126	-	-	-	20	-	-	-	4
	M15	9	60	9	6	-	-	-	-	-	-	-	3

Table 6 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. propiger	Other	Other fish
Eastern edge-Prairies	M16	72	110	39	44	-	-	-	-	-	5	15	8
	M1	20	95	12	-	-	-	-	-	-	-	-	15
	R9	30	28	64	23	7	-	-	-	-	-	-	+
	H14	794	15	3176	12	-	-	-	-	612	18	152	-
	M11	1	30	2	+	+	-	-	-	1	-	-	-
	M12	18	55	20	+	-	-	-	-	-	-	-	18
	M27	149	60	149	2	30	-	-	10	80	-	2	25
Swiftsure Spit	R14	702	26	1620	702	-	-	-	-	-	-	-	-
	M25	5	15	20	+	-	-	-	3	2	-	-	-
	M26	111	55	121	+	10	-	-	-	86	-	-	15
	M27	149	60	149	2	-	-	-	10	80	-	2	57
	M23	1	15	4	+	-	-	-	-	-	-	-	1
	M24	+	45	+	+	-	-	-	-	-	-	-	-
	M22	+	35	+	-	-	-	-	-	-	-	-	-
Swiftsure Bank	M18	714	50	856	660	-	-	-	50	-	-	-	4
	M19	20	15	80	-	-	-	-	15	-	-	3	2
	M20	455	45	607	125	-	-	-	200	5	-	123	2
	M21	+	95	+	+	-	-	-	+	-	-	-	-
Southwest Corner	H5	576	30	1152	-	-	-	3	-	573	-	-	-

Table 6 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Southeast Corner	H8	2	5	24	+	-	-	-	-	2	-	-	-
	H9	8	15	32	7	-	-	-	-	1	-	-	-
	H10	5	6	50	5	-	-	-	+	-	-	-	-
Finger Bank	H11	1902	35	3261	45	-	-	-	1836	20	-	-	1
	H12	72	13	332	2	-	-	-	22	48	-	-	-
	H18	1	37	2	-	-	-	-	-	1	-	-	-
	M4	18012	85	12714	10	-	-	-	18000	-	-	2	-
	M7	1300	10	7800	-	-	-	-	1300	-	-	-	-
West Finger Bank	H17	35	35	60	+	+	-	-	35	-	-	-	-
	M13	+	15	+	-	-	-	-	-	-	-	+	-
Barkley Basin	H6	5	4	75	-	-	-	2	+	2	-	1	+
	H7	241	30	482	+	1	1	222	6	11	-	-	-
	M8	15	37	24	-	-	-	-	-	10	-	-	5
	M9	86	40	129	+	5	+	55	-	10	-	16	-
Cape Beale Basin	H13	23000	13	106154	-	-	-	-	23000	-	-	-	-
Trevor Channel	H19	564	30	1138	-	-	246	-	315	-	-	-	-
Juan de Fuca Trench	M2	51	35	87	5	8	-	18	6	-	-	-	12
	M3	50	80	38	3	+	-	5	18	6	-	-	18
	M17	84	95	53	4	-	-	-	25	-	-	-	51

Table 6 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Sydney Inlet	H1	994	15	3976	-	-	990	-	-	4	-	-	-
Tofino Inlet	H2	9	20	27	-	-	9	-	-	-	-	-	-
Millar Channel	H3	1907	8	14302	+	-	1892	5	-	10	-	-	-
	H4	462	17	1631	-	-	342	6	81	23	-	7	3

Table 7. Catch by species by the EASTWARD HO from the Strait of Georgia, Nov. 3-21, 1980.

	Tow No.	Total catch (kg)	Time (min)	Catch rate (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Victoria	14	836	13	3859	829	-	-	2	4	-	-	-	2
	15	564	17	1991	561	-	-	+	-	-	-	-	2
	16	160	27	356	139	-	-	+	-	-	-	-	-
	17	60	8	450	60	-	-	-	-	-	-	-	+
	18	791	32	1483	650	+	-	106	-	-	-	-	23
Swanson Channel	4	906	34	1599	900	-	-	-	-	-	-	-	6
	5	20	63	19	10	-	-	+	-	-	-	-	9
Plumper Channel	12	6	25	14	4	-	+	+	+	-	-	+	-
	13	7	30	14	5	-	+	1	-	-	-	-	1
Satellite Channel	6	12	25	29	5	-	-	1	-	-	-	-	6
Active Pass	11	2041	8	15308	2040	-	-	-	-	-	-	-	+
Trincomali Channel	9	504	20	1512	499	-	-	-	4	-	-	-	2
	10	34	35	585	337	-	-	-	-	-	-	-	4
Crofton	1	412	30	824	72	-	152	1	174	2	-	-	11
	2	190	30	381	5	-	70	1	104	2	-	-	7
	3	98	48	122	22	-	-	-	72	-	-	-	3
Yellow Point	7	1695	14	7264	1649	-	1	-	43	-	-	-	2
	8	1289	15	5156	1067	-	-	-	222	-	-	-	-
	23	200	17	706	40	+	+	+	154	-	-	-	5

Table 7 (cont'd)

	Tow No.	Total catch (kg)	Time (min)	Catch rate. (kg/h)	Catch (kg)								
					Herring	Eulachon	Hake	Pollock	Dogfish	S. flavidus	S. proriger	Other	Other fish
Deepwater Bay	19	827	6	8270	627	-	-	-	200	-	-	-	-
	20	777	15	3108	516	-	-	1	260	-	-	-	-
Lund	21	527	32	1506	-	-	157	329	41	-	-	-	-
Jervis Inlet	22	736	46	2007	-	-	114	613	9	-	-	-	-

Table 8. Estimated biomass (metric tons) by species and fish concentration on the west coast of Vancouver Island, September 9-26, 1980.

Area	Concentration number	Total biomass (metric tons)	Species Biomass (metric tons)								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other fish
Outer edge, Estevan Point	1	2060[a]	2060	-	-	-	-	-	-	-	-
Sydney Inlet	2	255	255	-	-	-	-	-	-	-	-
Outer edge, Clayoquot Canyon	3	445	445	-	-	-	-	-	-	-	-
Outer edge, Father Charles Canyon, north	4	1120	1120	-	-	-	-	-	-	-	-
Outer edge, Father Charles Canyon	5	1750	1750	-	-	-	-	-	-	-	-
Outer edge, Loudoun Canyon	6,7,8	3620	2880	-	-	-	890	-	-	-	-
Outer edge, Barkley Canyon	9	1040	480	150	-	-	15	5	340	-	50
Outer edge, Barkley Canyon south	10	15700	14600	-	-	-	150	150	790	-	-
Outer edge, Nitinat Canyon south	11	26500	26500	-	-	-	-	-	-	-	-
Outer edge, South Prairies	12	2690	2210	-	-	-	-	-	140	360	-
Washington coast	13,14, 32,33	2830	2320	-	-	-	-	-	140	370	-
Southwest Corner	14	2180	1840	-	-	-	-	25	300	25	-
Swiftsure Bank	26,27	8780	2720	-	-	-	6060	-	-	-	-
Southeast Corner	18	4420	4420	-	-	-	-	-	-	-	-
Barkley Basin	16,17	7660	-	-	6520	1920	150	-	-	-	80
Cape Beale Basin	19	1260	-	-	-	-	-	25	940	280	-
Prairies	20,23	95800	3840	-	56500	28700	1920	3840	-	-	950

Table 8 (cont'd)

Area	Concentration number	Total biomass (metric tons)	Species Biomass (metric tons)								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other fish
Swiftsure Spit	28,29,30	5140	190	-	4270	2[illegible]0	410	50	-	-	-
Finger Bank	21	130	-	-	-	-	5	130	-	-	-
Central Prairies	25	2760	110	-	940	330	520	420	380	-	50
Total		186140	67740	150	68230	31180	10120	4645	3030	1035	1130

[a]Biomass weights above 10,000 t are rounded to the nearest 100 t, from 100-10,000 t to the nearest 10 t and below 100 t to the nearest 5 t. Because of rounding, the total of the individual biomasses may not be the same as the Total Biomass.

Table 9. Estimated biomass (metric tons) by species and fish concentration off the west coast of Vancouver Island, Nov. 3-21, 1980.

Area	Concentration number	Total biomass (metric tons)	Species Biomass (metric tons)								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other fish
Outer edge, Estevan Point	45,46,47	290[a]	290	-	-	-	-	-	-	-	-
Off Estevan Point	44	640	640	-	-	-	-	-	-	-	-
Outer Edge, Father Charles Canyon	48,49,50 51,53	1790	1790	-	-	-	-	-	-	-	-
Off Long Beach	52,54,55	180	180	-	-	-	-	-	-	-	-
Outer edge, Loudoun Canyon	6,7,15	2620	1260	-	-	80	1100	150	-	-	25
Outer edge, Barkley Canyon	5	3150	-	-	-	-	-	410	2710	-	25
Outer edge, Nitinat Canyon	4	49100	23900	-	-	1490	20800	2980	-	-	-
Outer edge, South Prairies	1,2,	18300	8170	-	-	-	3810	5560	200	-	480
Central Prairies	13,14	2060	1100	-	-	-	800	-	65	25	65
Washington coast	10,11,12	7300	3100	-	80	-	150	2290	-	1700	-
Southwest Corner	8,16	270	220	40	-	10	-	-	-	-	-
Southeast Corner	9	3920	3300	-	-	-	110	510	-	-	-
Finger Bank East	17,22	620	520	-	-	10	80	-	-	-	-
Off Pachena Pt.	18,19	1210	1210	-	-	-	-	-	-	-	-
Barkley Basin	24	15000	-	290	5800	6710	290	1190	440	150	150
Cape Beale Basin	25	9990	-	-	5990	3590	200	200	-	-	-
Prairies	26,27	36600	-	-	22000	13200	740	740	-	-	-
Cape Beale Spit	28	130	-	-	-	-	-	+	100	25	-

Table 9 (cont'd)

Area	Concentration number	Total biomass (metric tons)	Species Biomass (metric tons)								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other fish
Swiftsure Bank	20,21,23	15700	7900	-	-	-	5370	-	150	-	2370
Finger Bank west	32	140	40	-	-	-	-	65	40	-	-
Prairies, east edge	29,30	500	80	-	-	-	5	340	50	+	5
Total		169510	53700	330	33870	25090	33455	14435	3755	1900	3120

[a]Biomass weights above 10,000 t are rounded to the nearest 100 t, from 100-10,000 t to the nearest 10 t and below 100 t to the nearest 5 t. Because of rounding, the total of the individual species biomasses may not be the same as the Total Biomass.

Table 10. Estimated biomasses (metric tons) by species and fish concentration off the west coast of Vancouver Island, March 9-27, 1981.

Area	Concentration number	Total biomass (metric tons)	Species Biomass (metric tons)								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other fish
Outer edge, off Estevan Pt	1	2790[a]	1400	-	-	-	-	90	1310	-	-
Off Estevan Point	2	40	25	-	-	-	-	25	-	-	-
Outer edge, Clayoquot Canyon	3	3520	-	40	-	280	970	1600	-	570	80
Off Sydney Inlet	4	1130	1000	50	-	-	30	50	-	-	-
Outer edge, Father Charles Canyon	5	410	370	10	-	-	10	10	-	-	-
Outer edge, Loudoun Canyon	6	2320	2070	90	-	-	80	90	-	-	-
Outer edge, Loudoun Canyon/Barkley Canyon	7,8	1030	910	40	-	-	25	40	-	-	-
Outer edge, Nitinat Canyon	9	3160	2820	130	-	-	100	130	-	-	-
Outer edge, South Prairies	14,15	5540	4170	-	-	-	50	280	-	1040	-
Washington coast	16,17	5610	4470	-	-	-	760	-	50	220	100
La Perouse Bank	18,36	580	460	-	-	-	80	-	5	25	10
Southwest Corner	10	970	860	40	-	-	25	40	-	-	-
Southeast Corner	11	50	50	-	-	-	-	-	-	-	-
Finger Bank	21	950	880	-	-	-	80	-	-	-	-
Finger Bank East	23	1130	1040	-	-	-	90	-	-	-	-
Swiftsure Bank	26,24	320	290	-	-	-	25	-	-	-	-
Swiftsure Spit	25,34	20400	12300	-	-	-	5320	-	-	2870	-
Central Prairies	32	130	100	-	-	-	25	-	+	5	+
	30,31	15	10	5	-	-	-	-	-	-	-

Table 10 (cont'd)

Area	Concentration number	Total biomass (metric tons)	Species Biomass (metric tons)								
			Herring	Eulachon	Hake	Pollock	Dogfish	Yellowtail rockfish	Redstripe rockfish	Other rockfish	Other fish
Firing Range	B5	930	-	10	-	500	50	230	-	50	90
Barkley Basin	13	13300	-	140	-	7120	670	3230	-	800	1350
Prairies east	20	21000	200	630	-	-	11800	6930	-	840	630
Juan de Fuca Trench	33	41400	-	2070	-	-	12400	24000	-	-	2900
Juan de Fuca Strait	35	670	40	40	-	100	180	25	-	-	280
Finger Bank west	27	710	-	-	-	-	-	710	-	-	-
Central Prairies	29	530	-	-	-	-	-	-	-	530	-
Cape Beale Basin	22	5820	-	-	-	-	5820	-	-	-	-
Southwest edge	19	50	-	-	-	-	-	50	-	-	-
Total		134505	33465	3295	-	8000	38590	37530	1365	6950	5440

[a]Biomass weights above 10,000 t are rounded to the nearest 100 t, from 100-10,000 t to the nearest 10 t and below 100 t to the nearest 5 t. Because of rounding, the total of the individual species biomasses may not be the same as the Total Biomass.

Table 11. Estimated biomass (metric tons) by species and region in Barkley and Clayoquot Sounds, March 9-27, 1981.

Area	Concentration Number	Total Biomass (metric tons)	Species Biomass (metric tons) Herring	Hake	Pollock	Dogfish	Rockfish
Herring							
Barkley Sound							
Toquart Bay	1	1.0	1.0	-	-	-	-
Mayne Bay	2	1.6	1.6	-	-	-	-
Sechart Ch.	3	6.9	6.9	-	-	-	-
Bryant Isl.	4	2.0	2.0	-	-	-	-
Macoah Pass	5	82.2	82.2	-	-	-	-
Sargeson Bk.	6	6.6	6.6	-	-	-	-
Fraser Isl.	7	115.0	115.0	-	-	-	-
Pinnacle Rk.	8	0.1	0.1	-	-	-	-
Off Cape Beale	9	0.9	0.9	-	-	-	-
Bamfield	10	4.5	4.5	-	-	-	-
Voss Pt.	11	9.6	9.6	-	-	-	-
Subtotal		230.6	230.6	-	-	-	-
Clayoquot Sound							
Meares Isl. Area							
Off Lennard Isl.	12	10.5	10.5	-	-	-	-
Arnet Isl.	13[a]	0.2	0.2	-	-	-	-
Stockhom Isl.	14[a]	0.2	0.2	-	-	-	-
Arukum Isl..	15[a]	1.6	1.6	-	-	-	-
Lemmens In.	16[a]	0.9	0.9	-	-	-	-
Auseth Pt.	17[a]	0.2	0.2	-	-	-	-
Fortune Ch.	18	8.6	8.6	-	-	-	-
Off Father Charles Ch.	19	18.4	18.4	-	-	-	-
Father Charles Ch.	20	74.8	74.8	-	-	-	-
Robert Pt.	21	0.4	0.4	-	-	-	-
Elbow Bk.	22	13.5	13.5	-	-	-	-
Maurus Pt.	23[a]	0.4	0.4	-	-	-	-

Table 11 (cont'd)

Area	Concentration Number	Total Biomass (metric tons)	Species Biomass (metric tons) Herring	Hake	Pollock	Dogfish	Rockfish
Near Robert Pt.	24[a]	5.2	5.2	-	-	-	-
Epper Pass	25[a]	5.7	5.7	-	-	-	-
Yellow Bk.	26	2.6	2.6	-	-	-	-
Bedwell St.	27	18.9	18.9	-	-	-	-
Near Epper Pass.	28	4.8	4.8	-	-	-	-
Calmus Pass	29	0.6	0.6	-	-	-	-
Subtotal		167.6	167.6	-	-	-	-
Bawden Bay/Whitepine Cove							
Off Russell Ch.	30	27.9	27.9	-	-	-	-
Bawden Bay area	31	159.8	159.8	-	-	-	-
Subtotal		187.7	187.7	-	-	-	-
Sydney Inlet							
Off Sydney Inlet	32	69.9	69.9	-	-	-	-
Sydney Inlet	33	172.2	172.2	-	-	-	-
Subtotal		242.1	242.1	-	-	-	-
Hake							
Barkley Sd.							
Starlight Reef	1	5.2	-	2.3	-	2.9	-
Loudoun Ch.	2	9.5	-	4.2	-	5.3	-
Outer Imperial Eagle	3	140.0	-	61.1	+	78.2	-
In. Imperial Eagle	4	803.4	-	350.4	+	448.7	-
Trevor Ch.	5	309.5	-	125.2	+	173.1	-
Subtotal		1268.0	-	553.1	-	708.2	-

Table 11 (cont'd)

Area	Concentration Number	Total Biomass (metric tons)	Species Biomass (metric tons). Herring	Hake	Pollock	Dogfish	Rockfish
Clayoquot Sound							
Tofino Inlet	6	183.8	-	183.8	-	-	-
Fortune Ch.	7	35.1	-	35.1	-	-	-
Millar Ch.	8	85.7	-	74.3	0.7	7.5	3.0
Herbert In.	9	183.9	-	159.3	1.4	16.1	6.5
Shelter In.	10	76.9	-	76.8	-	-	-
Sydney In.	11	276.5	-	276.5	-	-	-
Subtotal		2109.9	-	805.8	2.1	23.6	9.5
Rockfish							
Barkley Sd.							
Starlight Pt.	1	3.6	-	-	-	-	3.6
Loudoun Ch.	2	0.3	-	-	-	-	0.3
Outside Imp. Eagle	3	27.6	-	-	-	-	27.6
Inside Imp. Eagle	4	1.0	-	-	-	-	1.0
Trevor Ch.	5	0.3	-	-	-	-	0.3
Subtotal		32.8	-	-	-	-	32.8
Clayoquot Sd.							
Hayden Pass.	6	0.4	-	-	-	-	0.4
Sydney In.	7	0.6	-	-	-	-	0.6
Subtotal		1.0	-	-	-	-	1.0
Subtotals by Region							
Barkley Sd.		1531.4	230.6	553.1	-	708.2	32.8
Clayoquot Sd.							
Meares Isl. Region		386.5	167.6	218.9	-	-	-
Bawden/Whitepine		457.7	187.7	233.5	2.1	23.6	9.9
Sydney Inlet		596.1	242.1	353.4	-	-	0.6
Grand Total		2971.7	928.0	1358.9	2.1	731.8	4[illegible].3

aConcentration numbers 13 to 17 and 23 to 25 were surveyed by launch.

Table 12. Actual and standardized catches made in the experimental survey area, Sept. 21-22, 1980.

Tow no.		Depth range fished (m) from bottom	Distance towed (n.m.)	Actual catch (kg)	Standardized catch (kg) for 1.5 naut. mi.
OK 80-1	-38	0-18	1.7	114.5	101
	-39	0-18	1.1	2728.8	3721
	-40	4-22	1.2	37.0	46
	-41	2-20	1.4	6363.6	6818
	-42	6-24	1.4	2500.0	2679
	-43	4-22	1.5	347.7	348
	-44	0-18	1.4	135.5	140
	-45	4-22	1.5	31.8	32
	-46	1-19	1.6	456.8	428
	-49	6-24	1.3	76.7	88
	-50	0-18	2.3	2727.0	1178

Table 13. Estimates of relative variance for the major fish concentrations encountered off the west of coast of Vancouver Island in September and November, 1980, and March, 1981.

	GBR80-7 September			GBR80-8 November			GBR81-3 March					
	Concentration number	Number of observations	Relative variance (random)	Concentration number	Number of observations	Relative variance (random)	Concentration number	Number of observations	Relative variance (random)	Number of transects	Relative variance (cluster)	Relative variance (auto-correlation) Bayley & Hemmersley
Herring												
	Hel	27	.246	1	14	.512	1	30	.275	3	.140	.269
	2	10	.259	3	12	.747	2	72	.245	10	.216	.242
	3	34	.591	4	65	.197	3	6	.454	1	-	.423
	4	63	.164	5	29	.095	4	98	.128	9	.151	.129
	5	16	.158	6	10	.210	5	104	.155	12	.168	.154
	7	11	.299	9	26	.310	8	14	.400	3	.400	.385
	9	11	.555	11	17	.269	9	13	.365	3	.223	.345
	10	13	.375	19	13	.458	11	8	.257	2	.025	.252
	18	10	.226	21	11	.421	12	16	.362	2	.064	.342
				22	18	.153	13	35	.311	4	.393	.302
							14	9	.360	2	.207	.339
Hake and Rockfish												
Hake	1	15	.153	24	54	.151	B1	42	.258	5	.206	.254
	2	9	.521	25	30	.119	B2&3	56	.199	7	.259	.202
	3&4	155	.093	26	51	.128	B4	51	.199	9	.252	.194
	6	8	.176	27	43	.109	B5	11	.184	1	-	.182
Rockfish	1	8	.306	33	13	.435	B6	8	.124	2	.002	.123
							B8	17	.177	4	.261	.179

Table 14. Percentage age composition and average length (mm) at age for herring in each sample from the west coast of Vancouver Island, Sept. 9-26, 1980.

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Off Sydney Inlet	GBR80-7-2	1.06	96.81	1.06	1.06	-	-	-	-	-	-
		159.0	143.7	160.0	192.0	-	-	-	-	-	-
Off Clayoquot Canyon	GBR80-7-3	4.17	77.78	18.06	-	-	-	-	-	-	-
		134.3	142.5	160.3	-	-	-	-	-	-	-
Hel. North of Barkley Canyon	OK80-1-22	-	22.11	50.53	14.74	8.42	2.11	1.05	1.05	-	-
		-	150.5	175.8	184.6	203.6	217.5	197.0	230.0	-	-
	OK80-1-24	-	47.78	35.56	14.44	1.11	1.11	-	-	-	-
		-	149.4	176.6	196.9	211.0	235.0	-	-	-	-
Average %		-	34.95	43.05	14.59	4.77	1.61	.52	.52	-	-
He2 Barkley Canyon	OK80-1-21	-	33.33	57.78	7.78	1.11	-	-	-	-	-
		-	150.4	174.7	189.0	201.0	-	-	-	-	-
	OK80-1-56	-	1.06	50.00	31.91	9.57	7.45	-	-	-	-
		-	180.0	189.0	196.4	207.1	220.3	-	-	-	-
	OK80-1-56	-	1.08	39.78	33.33	11.83	8.60	3.23	1.08	1.08	-
		-	161.0	189.1	199.3	211.0	216.1	230.7	239.0	200.0	-
	OK80-1-57	-	4.76	53.97	26.98	11.11	1.59	1.59	-	-	-
		-	157.0	181.3	199.9	212.7	221.0	229.0	-	-	-
Average %		-	10.06	50.38	25.08	8.41	4.41	1.20	0.27	0.27	-
He3. Barkley Canyon	OK80-1-11	-	-	9.19	22.99	22.99	29.88	8.05	4.60	1.15	1.15
		-	-	189.6	203.0	221.6	222.1	238.4	235.4	267.0	240.0
	OK80-1-53	-	-	11.11	14.44	17.78	34.44	14.44	5.56	2.22	-
		-	-	184.3	201.4	217.1	224.8	229.7	232.8	237.5	-
	OK80-1-54	-	-	14.77	26.14	18.18	28.41	6.82	4.55	1.14	-
		-	-	189.4	203.6	217.7	223.7	227.7	240.0	258.0	-
	OK80-1-55	-	1.08	34.41	48.39	13.98	1.08	1.08	-	-	-
		-	147.0	189.5	199.7	208.5	225.0	245.0	-	-	-

Table 14 (cont'd)

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
He3. Barkley Canyon (cont'd)	GBR80-7-7	-	-	9.64	19.28	21.69	28.92	19.28	1.20	-	-
		-	-	198.5	199.1	213.1	221.7	230.0	230.0	-	-
	GBR80-7-7	-	-	2.50	18.75	33.75	32.50	8.75	3.75	-	-
		-	-	198.0	205.3	215.3	222.2	231.4	239.0	-	-
	GBR80-7-5	-	-	6.74	17.98	21.35	30.34	17.98	5.62	-	-
		-	-	190.3	203.4	214.1	225.0	233.4	241.2	-	-
	GBR80-7-4	-	-	16.18	39.71	10.29	17.65	10.29	5.88	-	-
		-	-	187.3	199.7	206.1	221.7	231.4	235.8	-	-
Average %		-	0.14	13.07	25.96	20.00	25.40	10.54	3.90	0.56	0.14
He4. South of Nitinat Canyon	OK80-1-6	-	5.13	25.64	17.95	25.64	15.38	8.97	1.28	-	-
		-	163.0	191.1	198.4	215.8	215.2	222.0	238.0	-	-
	OK80-1-7	-	8.99	41.57	15.73	15.73	13.48	2.25	2.25	-	-
		-	149.4	185.9	199.8	219.0	227.8	238.0	248.0	-	-
	OK80-1-8	-	34.09	36.36	25.00	1.14	2.27	1.14	-	-	-
		-	152.3	177.1	190.4	205.0	213.0	210.0	-	-	-
	OK80-1-10	-	-	26.67	36.67	18.89	10.00	5.56	2.22	-	-
		-	-	182.5	197.6	208.9	226.3	231.0	233.0	-	-
	OK80-1-31	-	11.36	39.77	27.77	13.64	5.68	2.27	-	-	-
		-	145.5	186.9	196.9	211.1	224.4	229.5	-	-	-
	OK80-1-33	-	85.86	10.00	2.22	-	-	-	2.22	-	-
		-	144.1	147.4	181.0	-	-	-	257.0	-	-
	OK80-1-35	-	18.82	58.82	15.29	5.88	1.18	-	-	-	-
		-	151.0	179.1	198.8	204.2	248.0	-	-	-	-
	OK80-1-35	-	81.69	14.08	4.23	-	-	-	-	-	-
		-	148.5	161.8	180.3	-	-	-	-	-	-
	OK80-1-38	-	21.18	63.53	12.94	2.35	-	-	-	-	-
		-	147.9	177.1	194.2	215.0	-	-	-	-	-
	OK80-1-39	-	-	26.14	52.27	12.50	5.68	1.14	1.14	1.14	-
		-	-	188.9	194.9	215.7	223.0	228.0	223.0	243.0	-

Table 14 (cont'd)

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
He4. South of Nitinat Canyon (cont'd)	OK80-1-40	-	46.51	48.84	3.49	1.16	-	-	-	-	-
		-	148.0	173.2	201.3	222.0	-	-	-	-	-
	OK80-1-41	-	9.89	53.85	29.67	3.30	3.30	-	-	-	-
		-	158.2	180.1	194.7	211.7	228.0	-	-	-	-
	OK80-1-42	-	16.87	56.63	19.28	3.61	3.61	-	-	-	-
		-	149.1	177.2	191.1	204.0	218.3	-	-	-	-
	OK80-1-42	1.12	10.11	39.33	28.09	8.99	10.1	2.25	-	-	-
		139.0	148.3	178.2	194.0	213.0	217.6	224.0	-	-	-
	OK80-1-43	-	17.86	45.24	22.62	7.14	4.76	2.38	-	-	-
		-	149.9	181.2	194.6	221.0	233.3	226.0	-	-	-
	OK80-1-44	-	3.41	22.73	37.50	22.73	10.23	1.14	2.27	-	-
		-	152.3	188.2	202.9	214.4	221.7	253.0	228.0	-	-
	OK80-1-45	-	65.62	20.25	8.86	3.80	1.27	-	-	-	-
		-	147.9	168.1	202.6	205.0	214.0	-	-	-	-
	OK80-1-45	-	43.21	32.10	14.81	4.94	2.47	2.47	-	-	-
		-	147.7	172.0	194.5	204.2	231.0	236.5	-	-	-
	OK80-1-46	-	10.87	39.13	29.35	14.13	4.35	1.09	1.09	-	-
		-	148.3	181.1	195.3	214.0	216.8	228.0	228.0	-	-
	OK80-1-49	1.22	85.37	12.20	1.22	-	-	-	-	-	-
		146.0	144.1	154.5	202.0	-	-	-	-	-	-
	OK80-1-50	-	1.15	22.99	35.64	21.84	9.20	6.90	2.30	-	-
		-	156.0	179.7	196.7	211.4	221.9	224.7	226.5	-	-
	OK80-1-50	-	-	32.98	32.98	15.96	11.70	2.13	3.19	1.06	-
		-	-	184.6	199.4	213.6	219.7	216.0	227.0	230.0	-
Average %		0.11	26.26	34.49	21.50	9.24	5.21	1.80	.82	.10	-
He5. Southern Prairies	OK80-1-29	2.35	29.41	38.82	23.53	4.71	1.18	-	-	-	-
		148.5	153.1	178.2	183.0	209.2	204.0	-	-	-	-
	OK80-1-30	-	75.00	22.37	2.63	-	-	-	-	-	-
		-	151.2	167.8	194.0	-	-	-	-	-	-
Average %		1.18	52.21	30.60	13.08	2.36	0.59	-	-	-	-

Table 14 (cont'd)

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
He7. Southwest Corner	OK80-1-27	-	6.67	83.33	8.88	1.11	-	-	-	-	-
		-	163.5	177.1	189.6	204.2	-	-	-	-	-
	OK80-1-59	1.20	43.37	46.99	8.43	-	-	-	-	-	-
		136.0	143.0	167.6	181.4	-	-	-	-	-	-
	OK80-1-59	-	58.76	41.24	-	-	-	-	-	-	-
		-	149.0	171.5	-	-	-	-	-	-	-
Average %		.40	36.27	57.19	5.77	.37	-	-	-	-	-
He10&18 Swiftsure Bank	OK80-1-3	-	3.19	47.87	30.85	11.70	5.32	1.06	-	-	-
		-	148.7	183.0	197.3	205.8	212.0	231.0	-	-	-
He20 Central Prairies	OK80-1-12	-	5.56	11.11	26.67	17.78	17.78	15.56	3.33	1.11	1.11
		-	143.6	186.3	204.8	215.2	226.4	234.9	238.3	222.0	245.0
He9 Southeast Corner	OK80-1-19	-	-	15.73	42.69	21.35	15.73	4.49	-	-	-
		-	-	185.1	194.1	201.5	214.8	224.3	-	-	-
ROI Eastern Prairies	OK80-1-9	-	23.33	62.33	13.33	1.11	-	-	-	-	-
		-	151.5	179.1	193.2	204.2	-	-	-	-	-

Table 15. Percentage age composition and average length (mm) at age for herring in each sample from the west coast of Vancouver Island, Nov. 3-21, 1980.

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Off Nitinat Canyon HB80-1-4		-	1.28	14.10	12.82	17.95	24.36	12.82	8.97	5.13	2.56
		-	183.0	180.7	200.2	209.5	219.6	223.8	231.9	235.5	256.0
	4	-	-	4.28	21.43	17.14	17.14	18.57	15.71	1.43	4.29
		-	-	185.3	193.9	201.2	215.6	227.4	229.7	250.0	253.7
	4	-	1.38	11.11	18.05	19.44	25.00	15.28	6.94	2.78	-
		-	180.0	199.5	198.9	210.8	218.5	226.2	238.4	241.0	-
	17	-	66.13	16.13	6.45	4.84	1.61	3.22	1.61	-	-
		-	154.3	179.5	199.2	216.7	218.0	234.5	246.0	-	-
	17	-	68.25	20.63	1.59	6.35	-	3.17	-	-	-
		-	156.0	182.2	209.0	218.3	-	233.5	-	-	-
	17	-	63.08	13.85	12.31	4.62	4.62	1.54	-	-	-
		-	157.7	174.3	199.0	210.7	222.3	219.0	-	-	-
	18	-	1.51	13.64	28.79	18.18	19.70	15.15	3.03	-	-
		-	169.0	188.9	201.2	214.5	218.9	215.5	235.0	-	-
	18	-	1.41	30.99	18.31	16.90	23.94	5.63	2.82	-	-
		-	137.0	192.0	206.9	215.7	225.8	230.5	237.0	-	-
	18	-	-	13.72	33.33	13.72	25.49	9.80	3.92	-	-
		-	-	192.0	201.0	215.3	220.8	233.4	223.0	-	-
	19	-	-	1.59	14.28	14.28	38.09	19.05	12.70	-	-
		-	-	197.0	204.0	217.6	220.2	228.4	229.0	-	-
	19	-	-	1.43	11.43	14.28	32.86	14.28	24.28	1.43	-
		-	-	188.0	201.2	213.6	220.4	227.9	228.9	239.0	-
	19	-	-	1.72	17.24	15.52	48.28	13.79	3.45	-	-
		-	-	192.0	213.7	216.3	226.2	234.1	235.0	-	-
	20	-	-	10.71	7.14	25.00	33.93	10.71	8.93	3.57	-
		-	-	178.7	206.0	220.6	234.6	239.7	236.6	235.5	-
	23	-	2.10	22.10	15.79	17.89	18.95	13.68	7.37	1.05	1.05
		-	169.0	183.4	197.5	213.8	217.6	198.9	208.3	252.0	224.0

Table 15 (cont'd.)

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Oft Nitinat Canyon (cont'd)	HB80-1-23	-	1.14	30.68	22.73	11.36	14.77	14.77	4.55	-	-
		-	162.0	186.6	199.2	213.1	223.0	229.8	230.8	-	-
	23	-	2.30	24.14	21.84	17.24	14.94	9.20	6.90	2.30	1.15
		-	150.5	184.1	201.0	210.7	220.9	228.8	231.8	249.5	260.0
	28	-	83.33	12.50	4.17	-	-	-	-	-	-
		-	154.0	169.8	187.0	-	-	-	-	-	-
	36	1.37	38.36	31.51	15.07	2.74	5.48	2.74	2.74	-	-
		114.0	153.9	170.1	182.5	212.0	208.8	217.0	228.0	-	-
Average %		0.08	18.35	15.27	15.71	13.19	19.40	10.19	6.33	0.98	0.50
South of Nitinat Canyon	HB80-1-27	-	65.22	23.19	11.59	-	-	-	-	-	-
		-	160.0	173.3	185.9	-	-	-	-	-	-
	27	-	72.73	18.18	7.79	1.30	-	-	-	-	-
		-	163.0	172.4	188.5	204.0	-	-	-	-	-
	27	-	61.82	32.73	3.64	1.82	-	-	-	-	-
		-	161.0	178.6	183.5	210.0	-	-	-	-	-
Average %		-	66.59	24.70	7.67	1.04	-	-	-	-	-
Southern Praries	HB80-1-12	-	43.94	45.45	7.57	3.03	-	-	-	-	-
		-	154.0	182.3	197.4	216.0	-	-	-	-	-
	12	1.41	45.07	35.21	18.31	-	-	-	-	-	-
		155.0	160.8	177.4	193.6	-	-	-	-	-	-
	12	-	28.57	32.65	26.53	6.12	6.12	-	-	-	-
		-	161.1	185.9	194.2	215.3	222.3	-	-	-	-
	13	-	14.52	38.71	40.32	3.22	-	1.61	1.61	-	-
		-	157.4	184.1	185.2	207.5	-	225.0	227.0	-	-
	13	-	10.00	55.00	25.00	10.00	-	-	-	-	-
		-	160.5	174.4	187.5	211.5	-	-	-	-	-

Table 15 (cont'd)

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Southern Prairies (cont'd)	HB80-1-13	1.45	10.14	40.58	31.88	8.69	2.99	1.45	-	-	-
		160.0	166.1	179.6	191.6	196.5	219.5	211.0	-	-	-
Average %		0.48	25.37	41.27	24.94	5.18	1.52	0.51	0.27	-	-
Washington	HB80-1-9	-	91.67	8.33	-	-	-	-	-	-	-
		-	149.2	154.5	-	-	-	-	-	-	-
	9	-	68.23	29.11	1.18	-	-	1.18	-	-	-
		-	150.5	145.3	202.0	-	-	224.0	-	-	-
	9	2.22	65.55	31.11	1.11	-	-	-	-	-	-
		125.5	148.0	155.0	187.0	-	-	-	-	-	-
Average %		0.74	75.15	22.95	0.76	-	-	0.39	-	-	-
Southwest Corner	HB80-1-41	7.41	55.55	28.39	7.41	1.23	-	-	-	-	-
		110.3	143.8	150.7	184.0	199.0	-	-	-	-	-
Southeast Corner	HB80-1-21	-	12.50	56.25	14.06	7.81	3.13	-	1.56	3.13	1.56
		-	163.2	183.1	200.0	208.0	231.0	-	247.0	234.5	256.0
	21	-	5.26	40.35	19.30	14.03	8.77	7.02	3.51	-	1.75
		-	171.3	182.7	193.6	211.6	218.2	223.0	218.0	-	252.0
	21	-	6.78	62.71	13.56	5.08	6.78	5.08	-	-	-
		-	161.2	184.4	195.0	223.3	211.8	230.0	-	-	-
	24	-	5.49	40.66	29.67	8.79	8.79	3.30	3.30	-	-
		-	154.0	181.6	196.8	208.0	217.2	237.7	235.0	-	-
	24	-	5.13	32.05	25.64	12.82	15.38	3.85	2.56	2.56	-
		-	153.0	184.3	193.1	209.9	199.8	236.0	232.5	244.0	-
	24	-	1.39	31.94	29.17	22.22	8.33	5.55	1.39	-	-
		-	169.0	181.5	194.8	204.9	220.2	223.8	232.0	-	-
	25	-	57.41	31.48	11.11	-	-	-	-	-	-
		-	147.8	169.1	187.0	-	-	-	-	-	-
Average %			13.42	42.21	20.36	10.11	7.31	3.54	1.76	0.81	0.47

Table 15 (cont'd)

Area	Tow no.	Age									
		1	2	3	4	5	6	7	8	9	10
Swiftsure Bank	HB80-1-1	-	-	20.27	25.67	14.86	21.62	9.46	4.05	4.05	-
		-	-	189.7	199.2	204.2	224.0	231.3	226.3	242.7	-
	1	-	1.10	24.17	17.58	9.89	16.48	14.28	10.99	4.39	1.10
		-	180.0	187.8	201.1	208.4	227.3	232.2	241.4	238.5	226.0
	2	-	7.69	41.03	23.08	5.13	5.13	12.82	5.13	-	-
		-	155.7	183.2	201.9	214.0	222.5	235.2	245.0	-	-
	2	-	14.28	24.49	26.53	10.20	16.33	6.12	2.04	-	-
		-	159.1	185.2	197.7	221.4	232.0	234.3	235.0	-	-
Average %		-	5.77	27.49	23.22	10.02	14.89	10.67	5.55	2.11	0.28

Table 16. Percentage age composition and average length (mm) at age for herring in each sample from the west coast of Vancouver Island, March 9-27, 1981.

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Estevan Inlet	GBR81-3-1	-	45.31	40.62	14.06	-	-	-	-	-	-
		-	156.7	178.2	193.3	-	-	-	-	-	-
Loudoun Channel	GBR81-3-3	-	44.59	39.19	12.16	-	1.35	2.20	-	-	-
		-	151.8	171.9	198.0	-	205.0	218.5	-	-	-
Barkley Canyon	GBR81-3-6	-	2.46	53.28	22.13	9.02	6.56	6.56	-	-	-
to Nitinat Canyon		-	165.0	181.7	195.6	205.5	218.9	238.9	-	-	-
	7	-	7.45	58.21	25.38	2.99	5.97	-	-	-	-
		-	156.4	185.0	197.6	208.0	215.5	-	-	-	-
	8	-	1.69	30.51	27.12	16.95	15.25	5.01	1.69	1.69	-
		-	172.0	186.7	198.4	218.5	232.0	239.0	235.0	232.0	-
	MW81-1-14	-	54.54	27.27	13.64	4.54	-	-	-	-	-
		-	154.0	175.0	195.0	229.0	-	-	-	-	-
	HB81-1-15	-	4.44	62.22	22.22	6.67	2.22	2.22	-	-	-
		-	169.0	191.9	203.8	213.0	202.0	217.0	-	-	-
	16	-	18.52	59.26	18.52	-	3.70	-	-	-	-
		-	162.4	187.6	207.4	-	235.0	-	-	-	-
Average %		-	14.85	48.46	21.50	6.70	5.62	2.30	.28	.28	-
Prairies	GBR81-3-9	-	4.23	29.58	39.44	18.31	5.63	1.41	1.41	-	-
		-	168.0	183.3	197.9	216.3	212.8	217.0	230.0	-	-
	14	-	18.64	37.29	23.73	13.56	5.08	1.69	-	-	-
		-	163.0	185.2	198.8	210.2	209.0	202.0	-	-	-
Average %		-	11.44	33.44	31.59	15.94	5.36	1.55	.70	-	-
Nitinat Canyon to	MW81-1-15	-	79.63	9.26	3.70	3.70	-	1.85	1.85	-	-
Juan de Fuca Trench		-	156.9	176.2	190.0	223.0	-	230.0	250.0	-	-
	16	-	85.96	12.28	1.75	-	-	-	-	-	-
		-	147.2	152.3	202.0	-	-	-	-	-	-
Average %		-	82.80	10.77	2.73	1.35	-	.92	.92	-	-

Table 16 (cont'd)

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Nitinat Canyon to	GRB81-3-10	-	24.32	36.49	21.62	4.05	8.11	5.41	-	-	-
Juan de Fuca Trench		-	159.0	181.8	197.7	210.0	223.5	228.2	-	-	-
	11	-	9.46	37.84	32.43	12.16	8.11	-	-	-	-
		-	159.1	187.2	206.3	217.7	227.0	-	-	-	-
	12	-	34.00	40.00	22.00	2.00	2.00	-	-	-	-
		-	154.2	183.8	198.7	211.0	220.0	-	-	-	-
	13	-	3.12	32.81	32.81	15.62	10.94	1.56	1.56	1.56	-
		-	158.5	183.9	202.4	219.1	230.7	247.0	226.0	241.0	-
Average %		-	17.73	36.79	27.22	8.46	7.29	1.74	.39	.39	-
Southeast Corner	HB81-1-9	-	10.81	67.57	14.86	2.70	4.05	-	-	-	-
and Finger Bank		-	160.4	179.1	193.8	208.0	221.0	-	-	-	-
	10	-	48.44	32.81	9.38	3.12	4.69	-	-	1.56	-
		-	152.7	181.4	190.5	220.0	227.0	-	-	230.0	-
	12	-	-	50.00	30.00	-	-	10.00	-	10.00	-
		-	-	187.0	199.0	-	-	226.0	-	214.0	-
Average %		-	19.75	33.46	18.08	1.94	2.91	3.33	-	3.85	-
Swiftsure Bank	MW81-1-18	-	4.88	29.27	36.59	17.07	7.32	4.88	-	-	-
		-	164.5	188.5	202.6	216.3	220.4	221.5	-	-	-
	20	-	1.45	46.38	31.88	15.94	2.90	1.45	-	-	-
		-	163.0	186.5	200.4	212.4	226.0	223.0	-	-	-
Average %		-	3.17	37.82	34.24	16.51	5.11	3.17	-	-	-
Juan de Fuca	MW81-1-2	-	-	40.74	14.81	29.63	11.11	-	3.70	-	-
		-	-	185.4	207.2	210.6	201.0	-	214.0	-	-
	3	-	8.70	34.78	34.78	8.70	13.04	-	-	-	-
		-	145.0	185.1	198.6	208.0	220.0	-	-	-	-
Average %		-	4.35	37.76	24.80	19.17	12.08	-	1.35	-	-
Juan de Fuca	MW81-1-17	-	69.57	21.74	8.70	-	-	-	-	-	-
		-	148.8	176.2	190.0	-	-	-	-	-	-
	MW81-1-27	-	11.11	11.11	11.11	11.11	44.44	-	11.11	-	-
		-	160.0	193.0	208.0	220.0	214.8	-	214.0	-	-

Table 16 (cont'd)

Area	Tow no.	Age									
		1	2	3	4	5	6	7	8	9	10
Swiftsure Bank	MW81-1-18	-	4.88	29.27	36.59	17.07	7.32	4.88	-	-	-
		-	164.5	188.5	202.6	216.3	220.4	221.5	-	-	-
	20	-	1.45	46.38	31.88	15.94	2.90	1.45	-	-	-
		-	163.0	186.5	200.4	212.4	226.0	223.0	-	-	-
Average %		-	3.17	37.82	34.24	16.51	5.11	3.17	-	-	-
Juan de Fuca	MW81-1-2	-	-	40.74	14.81	29.63	11.11	-	3.70	-	-
		-	-	185.4	207.2	210.6	201.0	-	214.0	-	-
	3	-	8.70	34.78	34.78	8.70	13.04	-	-	-	-
		-	145.0	185.1	198.6	208.0	220.0	-	-	-	-
Average %		-	4.35	37.76	24.80	19.17	12.08	-	1.35	-	-
Juan de Fuca	MW81-1-17	-	69.57	21.74	8.70	-	-	-	-	-	-
		-	148.8	176.2	190.0	-	-	-	-	-	-
	MW81-1-27	-	11.11	11.11	11.11	11.11	44.44	-	11.11	-	-
		-	160.0	193.0	208.0	220.0	214.8	-	214.0	-	-

Table 17. Percentage age composition and average length (mm) at age for herring in each sample from the Strait of Georgia, Nov. 3-21, 1980.

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Victoria Area											
Trial Isl.	EH80-1-14A	-	29.47	58.95	9.47	1.05	1.05	-	-	-	-
		-	162.9	178.1	190.2	202.0	205.0	-	-	-	-
Victoria area	14B	-	24.17	49.45	21.98	3.30	1.10	-	-	-	-
		-	161.4	174.4	188.2	207.7	235.0	-	-	-	-
Albert Hd.	15	-	30.11	52.69	16.13	1.98	-	-	-	-	-
		-	155.6	172.8	188.5	185.0	-	-	-	-	-
William Hd.	16	-	8.69	51.09	28.26	4.35	3.26	3.26	1.09	-	-
		-	163.4	181.8	193.0	196.0	234.0	217.7	227.0	-	-
Albert Hd.	17	-	44.33	49.48	6.19	-	-	-	-	-	-
		-	157.8	169.1	181.8	-	-	-	-	-	-
Victoria	18	-	27.96	64.52	5.38	1.07	1.07	-	-	-	-
		-	158.6	169.0	179.0	181.0	229.0	-	-	-	-
Average %		-	27.46	54.36	14.57	1.96	1.08	.54	.18	-	-
Swanson-Satellite Area											
Plumper Sd	EH80-1-13	4.61	10.77	58.46	13.85	7.69	3.08	1.54	-	-	-
		87.0	144.7	174.7	194.2	214.4	214.0	231.0	-	-	-
Navy Channel	12	70.31	7.81	6.25	9.38	1.56	3.12	1.56	-	-	-
		86.9	136.2	181.8	194.7	210.0	230.5	210.0	-	-	-
Swanson Channel	5	8.23	10.59	34.12	28.23	7.06	9.41	2.35	-	-	-
		81.1	174.1	185.0	198.0	214.2	225.0	223.5	-	-	-
	4	-	10.11	34.83	30.34	10.11	7.86	5.62	1.12	-	-
		-	164.8	178.8	191.7	201.4	216.9	226.4	245.0	-	-
Satellite Channel	6	34.61	30.77	10.26	10.26	8.97	5.13	-	-	-	-
		96.6	136.4	174.6	185.1	199.6	212.0	-	-	-	-
Active Pass	11	-	3.49	18.60	43.02	17.44	10.46	5.81	-	1.16	-
		-	166.3	186.8	20.7	209.9	220.7	223.8	-	235.0	-
Average %		19.63	12.26	27.09	22.51	8.81	6.51	2.81	.19	.19	-

Table 17 (cont'd)

Area	Tow no.	Age 1	2	3	4	5	6	7	8	9	10
Trincomali Channel Area											
Walker Rock	10	-	-	28.23	32.94	17.64	16.27	4.70	-	-	-
		-	-	184.2	196.8	209.3	220.1	221.8	-	-	-
Porlier Pass	9	-	3.26	42.39	34.78	14.13	4.35	1.09	-	-	-
		-	170.0	186.3	195.7	205.5	220.0	223.0	-	-	-
Average %		-	1.63	35.31	33.86	15.89	10.31	2.90	-	-	-
Upper Stuart Channel											
Yellow Point Area	EH80-1-8	-	5.26	31.58	28.42	18.95	11.58	2.10	2.10	-	-
		-	171.0	191.2	196.6	212.8	220.2	233.0	225.0	-	-
	7	-	3.33	31.11	33.33	20.00	11.11	1.11	-	-	-
		-	160.7	180.0	192.0	209.4	215.5	213.0	-	-	-
Average %		-	4.30	31.35	30.88	19.48	11.35	1.61	1.05	-	-
Lower Stuart Channel Area											
Sansum Narrows	EH80-1-3	-	-	43.96	27.47	7.69	2.20	7.69	6.59	3.30	1.10
		-	-	188.0	198.5	204.1	234.5	249.1	244.8	243.3	231.0
Crofton	2	79.31	10.34	5.17	3.45	1.72	-	-	-	-	-
		95.91	99.50	143.0	189.5	205.0	-	-	-	-	-
Average %		39.66	5.17	24.56	15.46	4.71	1.10	3.85	3.29	1.65	.55
All samples pooled (%)		10.94	14.47	37.29	21.27	8.05	5.61	2.05	.61	.25	.06

Table 18. Percentage of immature and mature herring by age group in samples from the west coast of Vancouver Island, March 9-27, 1981.

Age	2			3			4			5+ older		
Maturity Stage	Percent		Total	Percent		Total	Percent		Total	Percent		Total
	1&2	3-8	no.	1&2	3-8	no.	1&2	3-8	no.	1&2	3-8	no.
GRB81-3-1	70	30	30	-	100	26	-	100	9	-	-	-
3	15	85	33	-	100	29	-	100	9	-	100	3
6	-	100	2	-	100	41	-	100	16	-	100	18
6B	-	100	1	4	96	26	9	91	11	-	100	9
7	40	60	5	-	100	39	-	100	19	-	100	7
8	100	-	1	-	100	18	-	100	16	-	100	24
9	-	100	3	-	100	20	-	100	28	-	100	19
10	39	61	18	4	96	27	-	100	17	-	100	13
11	75	25	8	-	100	30	-	100	24	-	100	17
12	35	65	17	-	100	20	-	100	11	-	100	2
13	-	100	4	-	100	20	-	100	21	-	100	21
14	18	82	11	-	100	22	-	100	15	-	100	12
MW81-1-2	-	-		-	100	11	-	100	4	-	100	12
3	50	50	2	-	100	8	-	100	8	-	100	5
14	75	25	12	33	67	6	-	100	3	-	100	1
15	5	95	44	-	100	5	-	100	2	-	100	4
16	71	29	49	28	72	7	-	-	-	-	-	-
18	-	100	1	-	100	10	-	100	16	-	100	14
20	-	100	1	-	100	32	-	100	23	-	100	14
17	19	81	16	-	100	5	-	100	2	-	-	-
27	-	100	1	-	100	1	-	100	1	-	100	9
HB81-1-10	16	84	31	-	100	22	-	100	6	-	100	6
12	-	-	-	-	100	5	-	100	3	-	100	2
15	-	100	2	-	100	28	-	100	10	-	100	5
16	-	100	5	-	100	17	-	100	5	-	100	1
9	-	100	8	2	98	50	-	100	11	-	100	2
Average[a]	34	66	305	1	99	525	+[b]	100	290	0	100	220

[a]Average-based on total numbers converted to percentage, not average of sample percentages.
[b]Represents less than 0.5%.

FIGURES

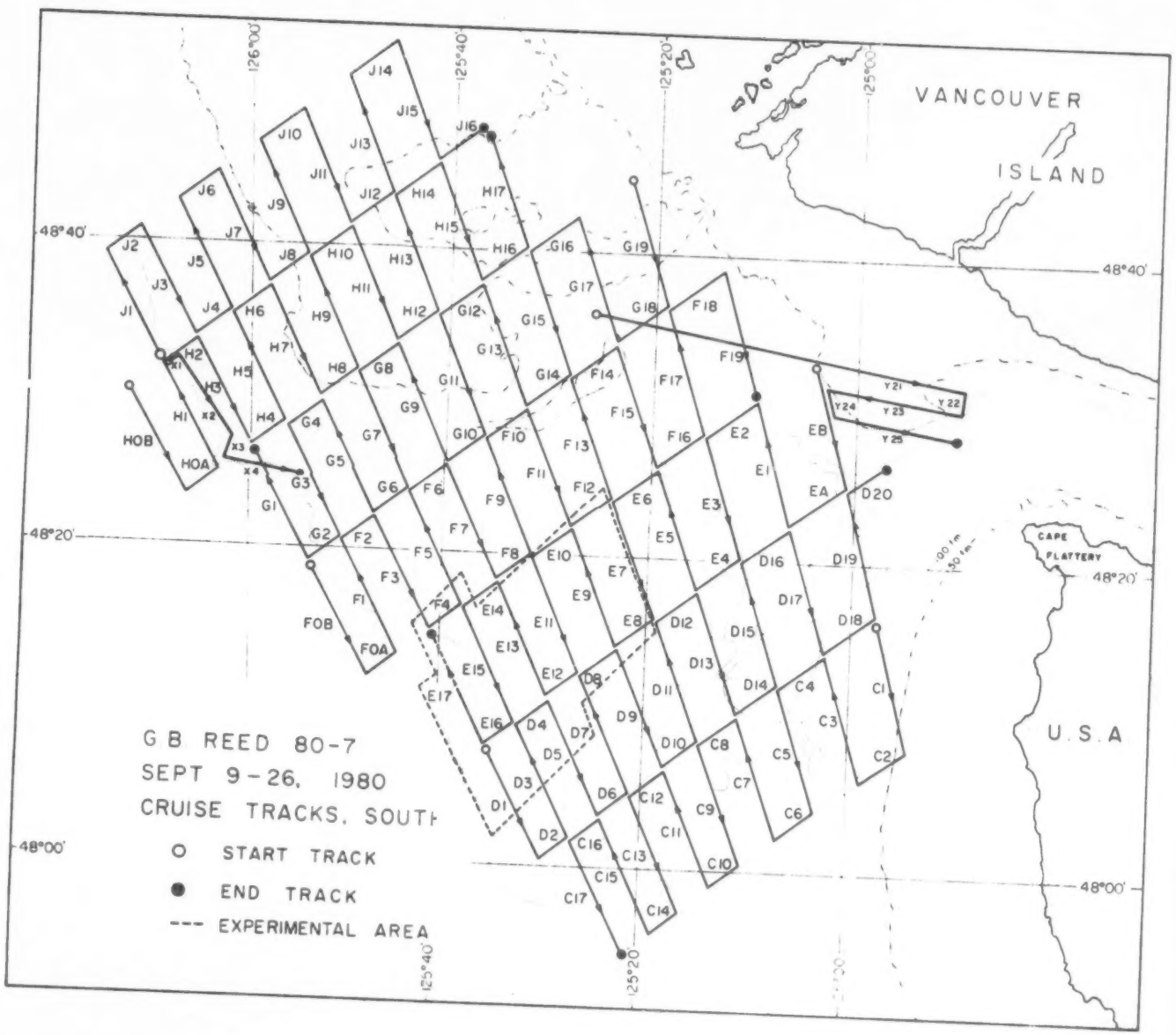

Fig. 1. Acoustic survey track-lines of the G.B. REED from Amphitrite Point to the Juan de Fuca Trench, Sept. 9-26, 1980.

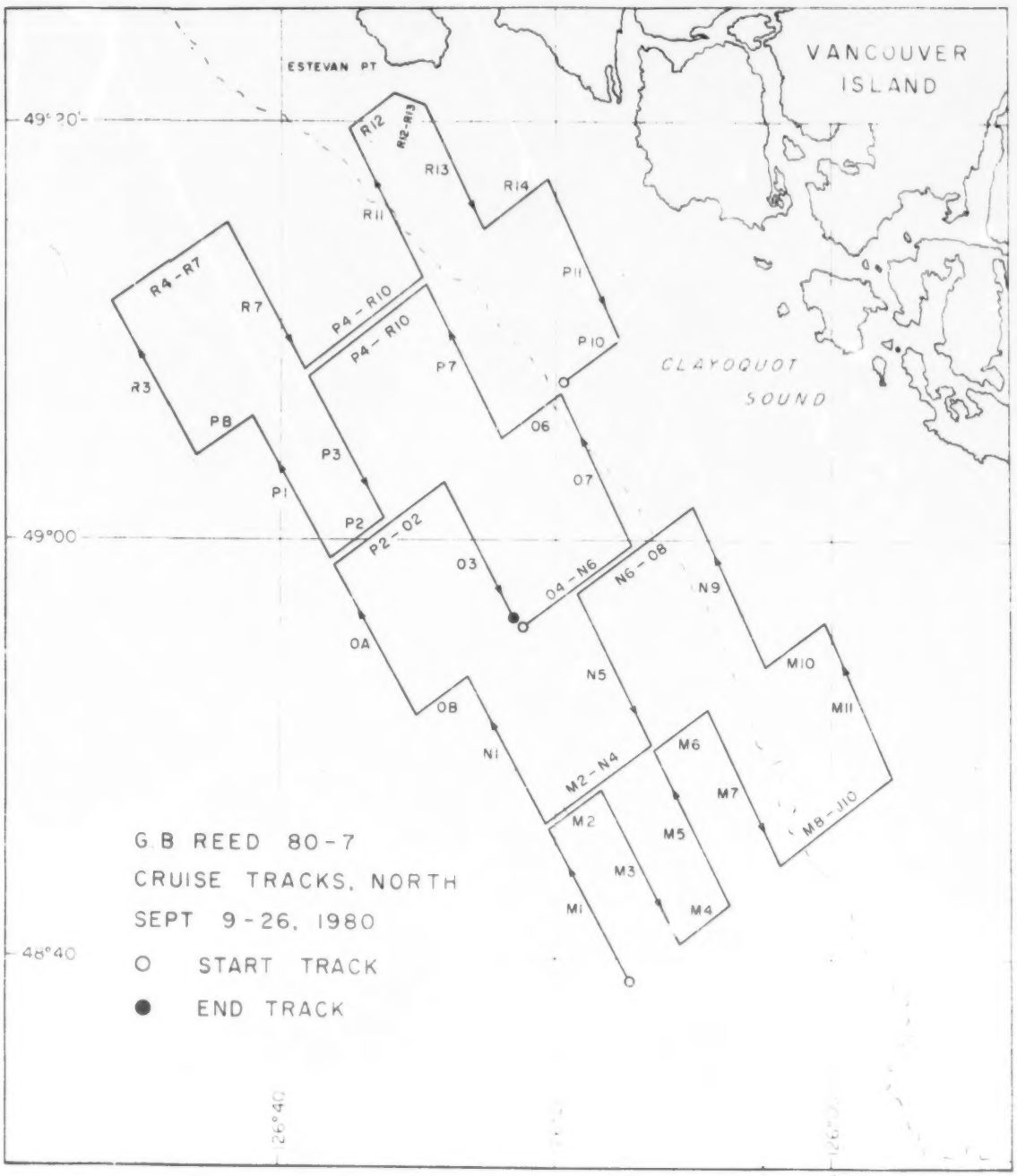

Fig. 2. Acoustic survey track-lines of the G.B. REED from Amphitrite Point to Estevan Point, Sept. 9-26, 1980.

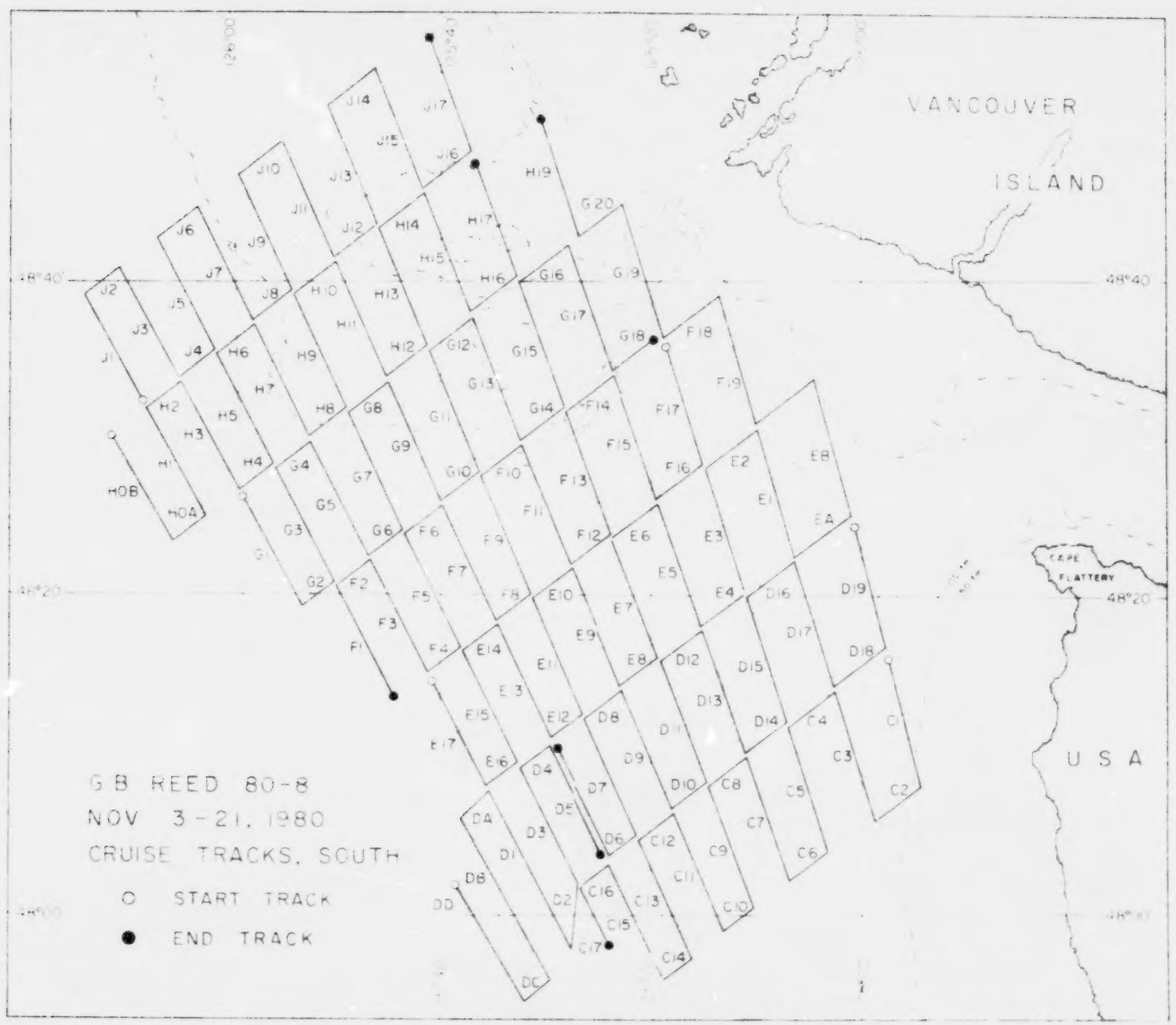

Fig. 3. Acoustic survey track-lines of the G.B. REED from Amphitrite Point to the Juan de Fuca Trench, Nov. 3-21, 1980.

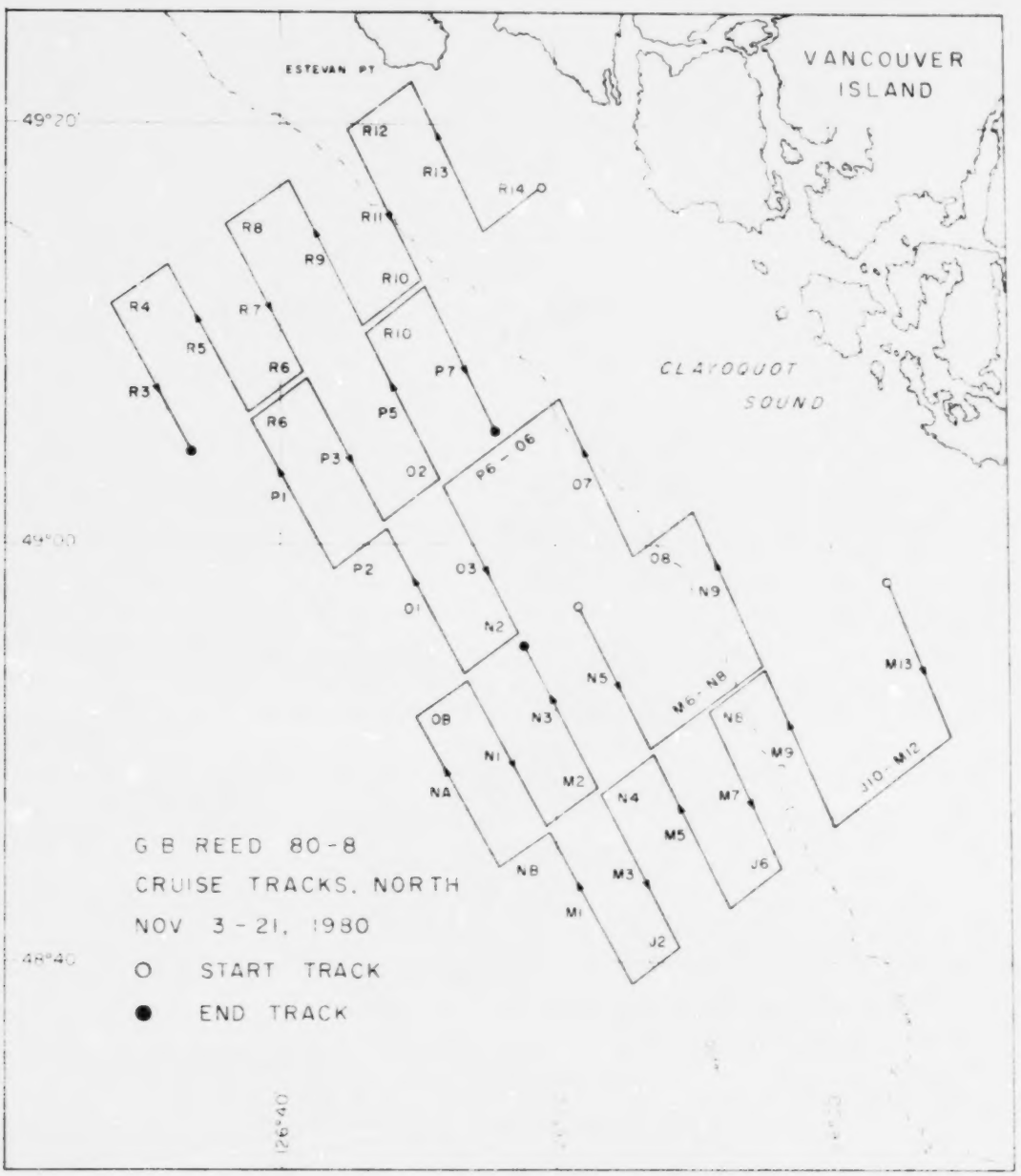

Fig. 4. Acoustic survey track-lines of the G.B. REED from Amphitrite Point to Estevan Point, Nov. 3-21, 1980.

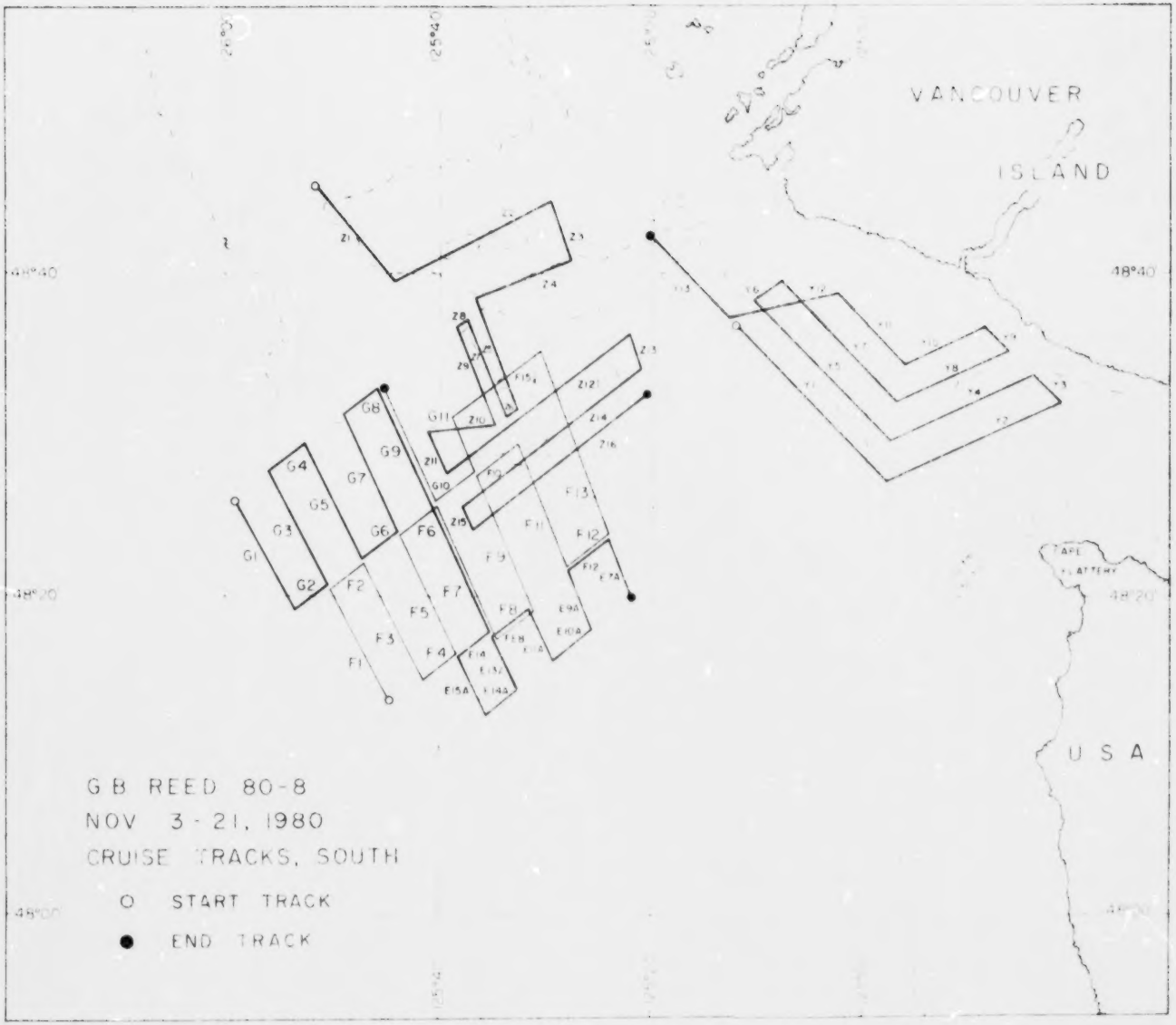

Fig. 5. Additional acoustic survey track-lines of the G.B. REED, from Amphitrite Point to the Juan de Fuca Trench, Nov. 3-21, 1980.

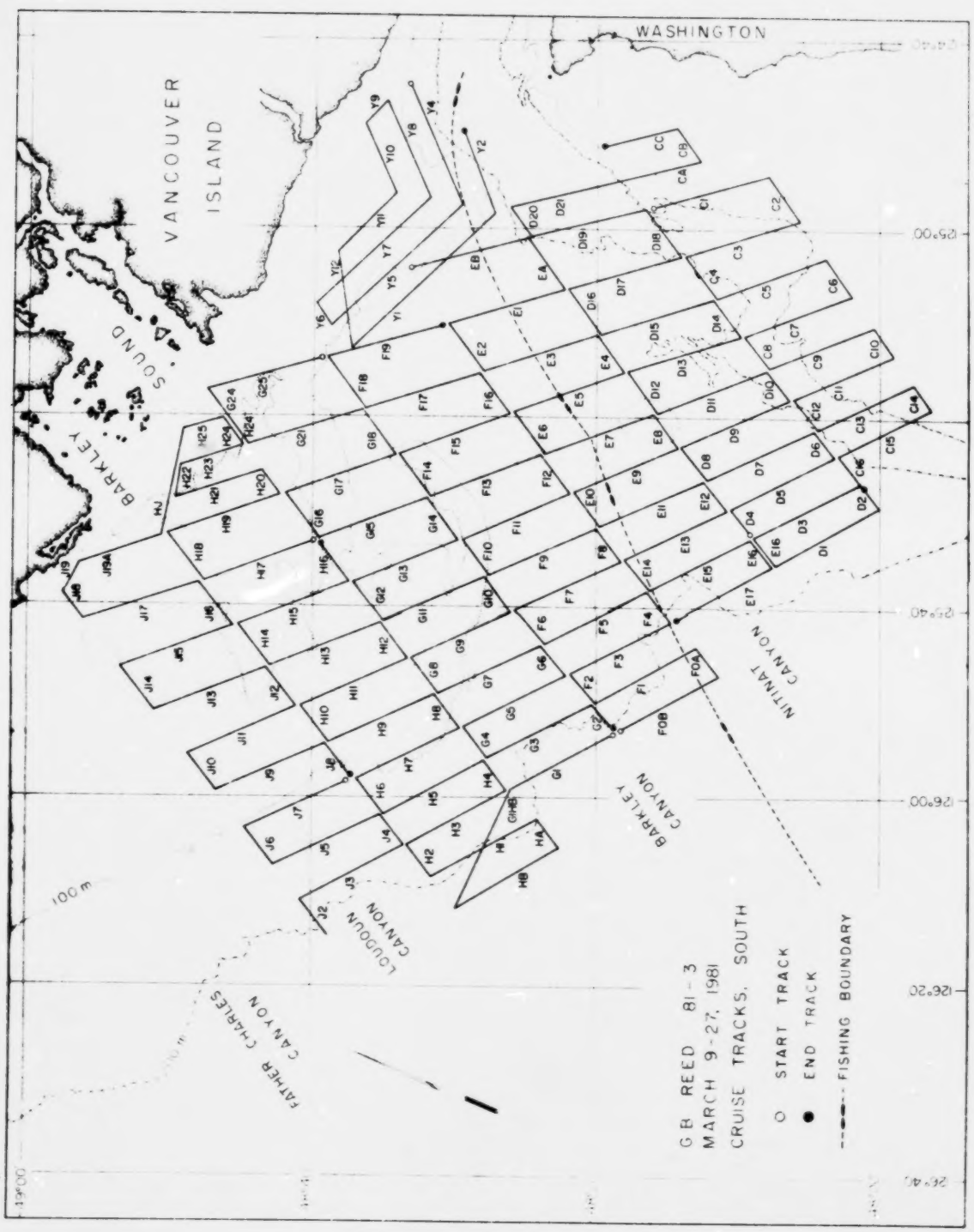

Fig. 6. Acoustic survey track-lines of the G.B. REED, from Amphitrite Point to the Juan de Fuca Trench, March 9-27, 1981.

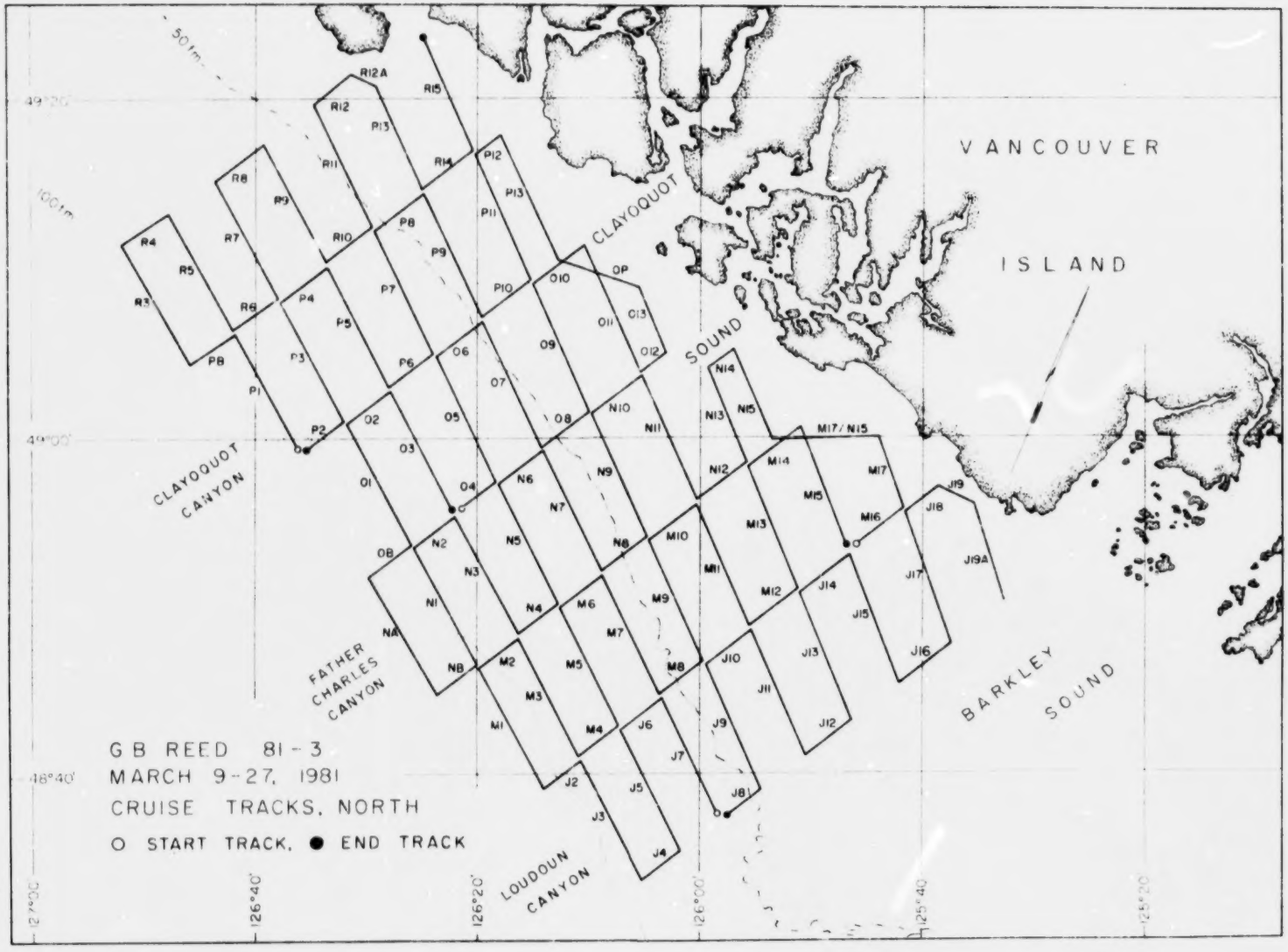

Fig. 7. Acoustic survey track-lines of the G.B. REED from Amphitrite Point to Estevan Point, March 9-27, 1981.

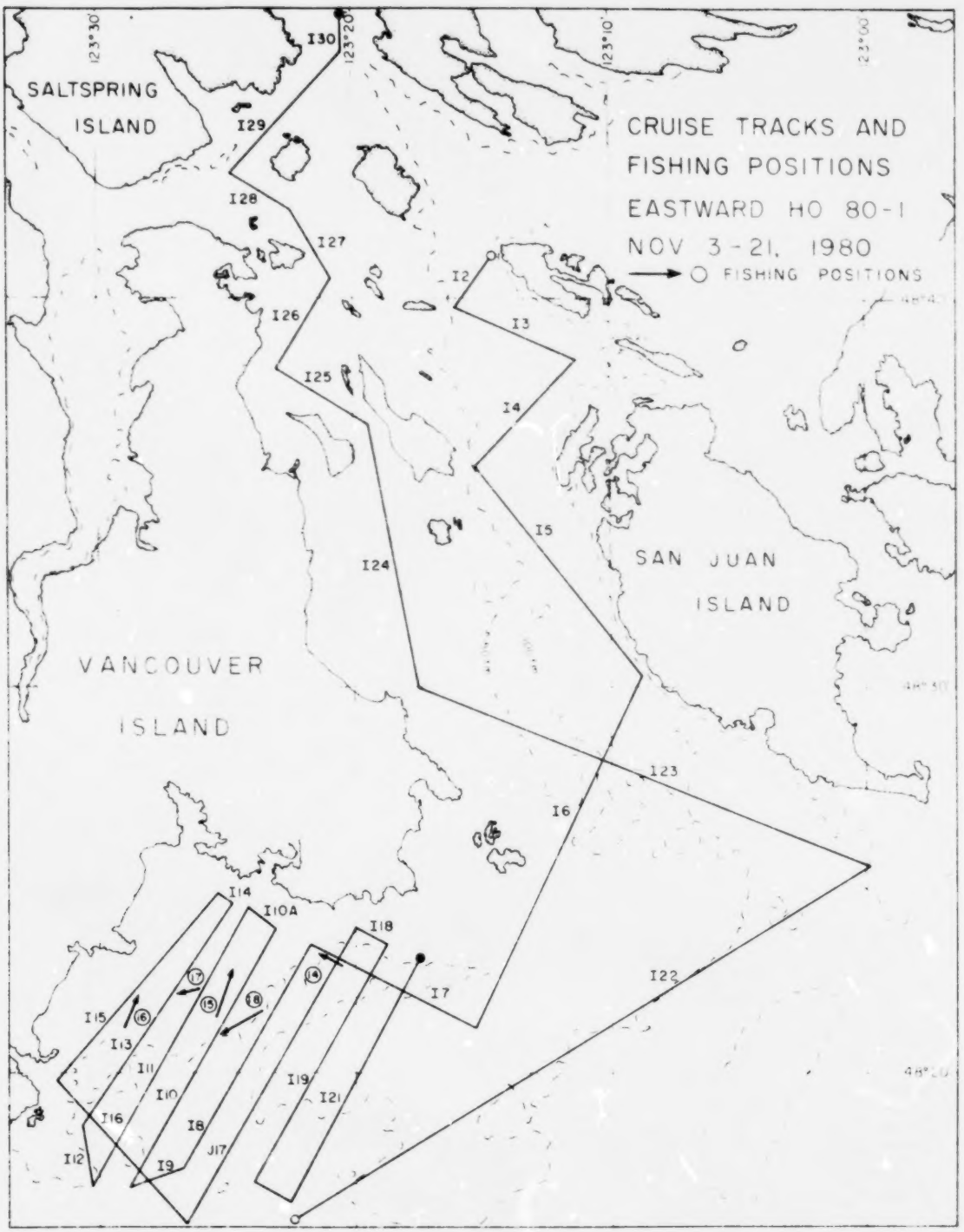

Fig. 8. Acoustic survey track-lines and fishing positions of the EASTWARD HO from Victoria to Saltspring Island, Nov. 3-21, 1980.

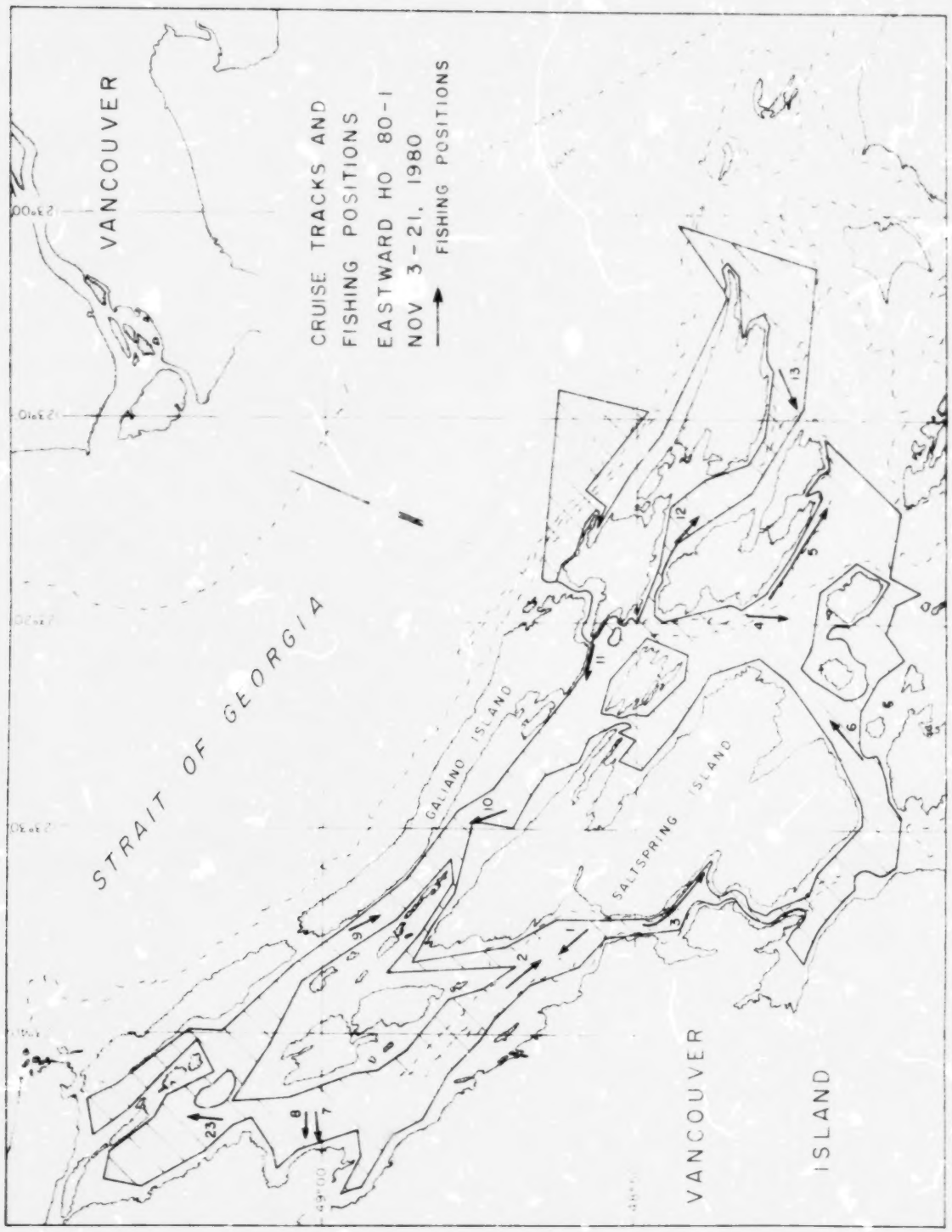

Fig. 9. Areas covered by the hydroacoustic survey, and fishing positions in the southern Strait of Georgia, EASTWARD HO, Nov. 3-21, 1980.

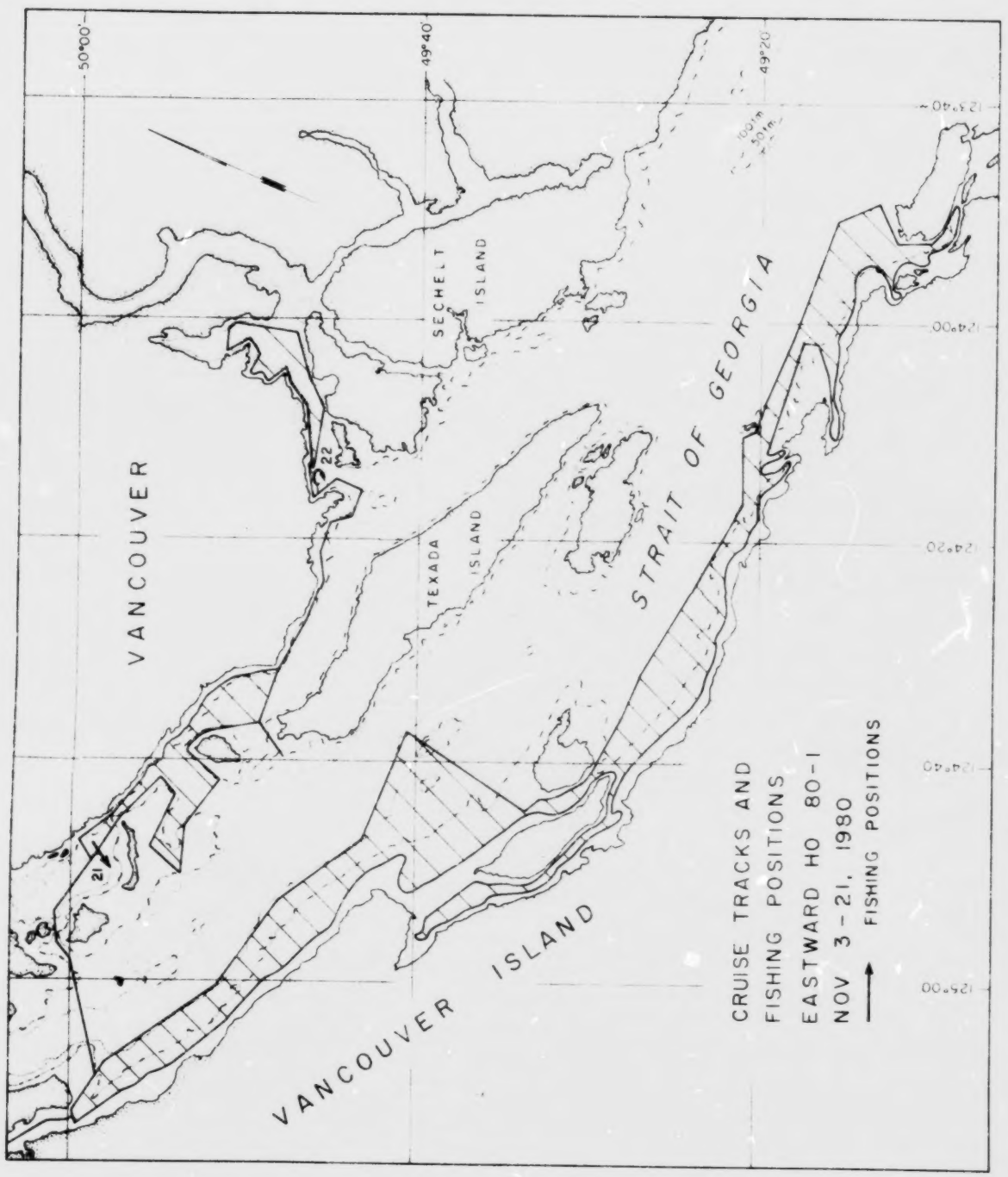

Fig. 10. Areas covered by the hydroacoustic survey, and fishing positions, in the central Strait of Georgia, EASTWARD HO, Nov. 3-21, 1980.

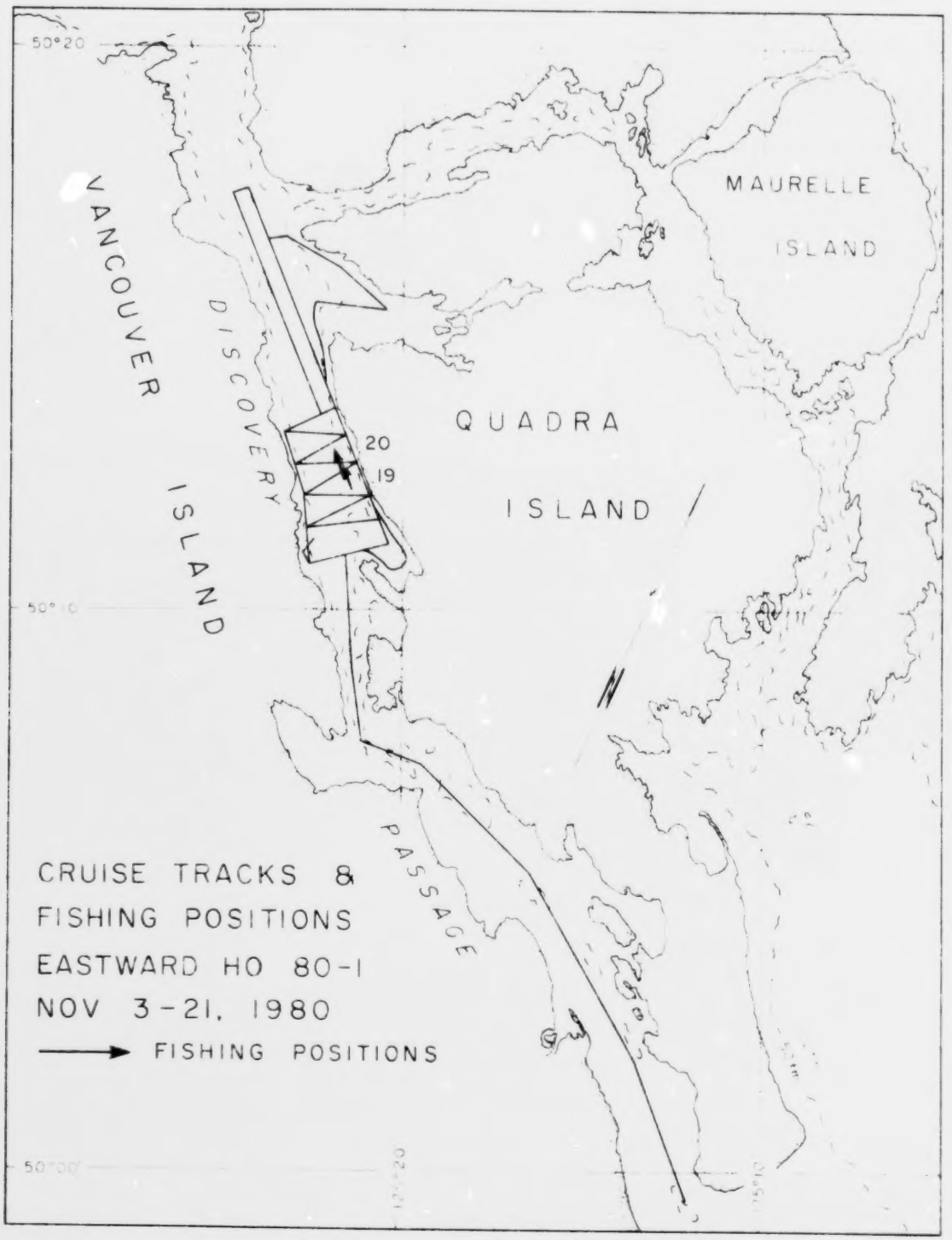

Fig. 11. Acoustic survey track-lines and fishing positions of the EASTWARD HO, northern Strait of Georgia, Nov. 3-21, 1980.

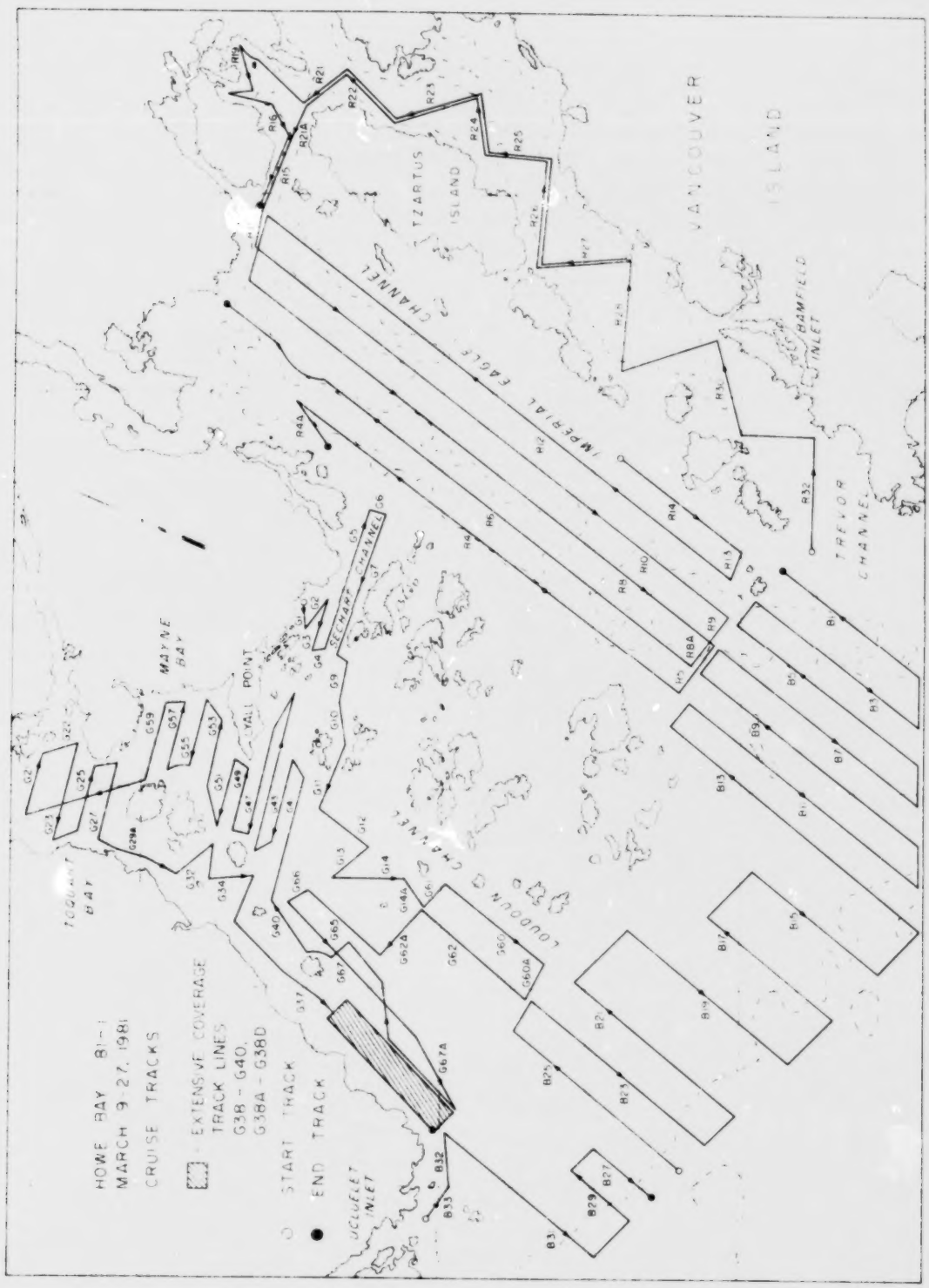

Fig. 12. Acoustic survey track-lines of the HOWE BAY, Barkley Sound, March 9-27, 1981.

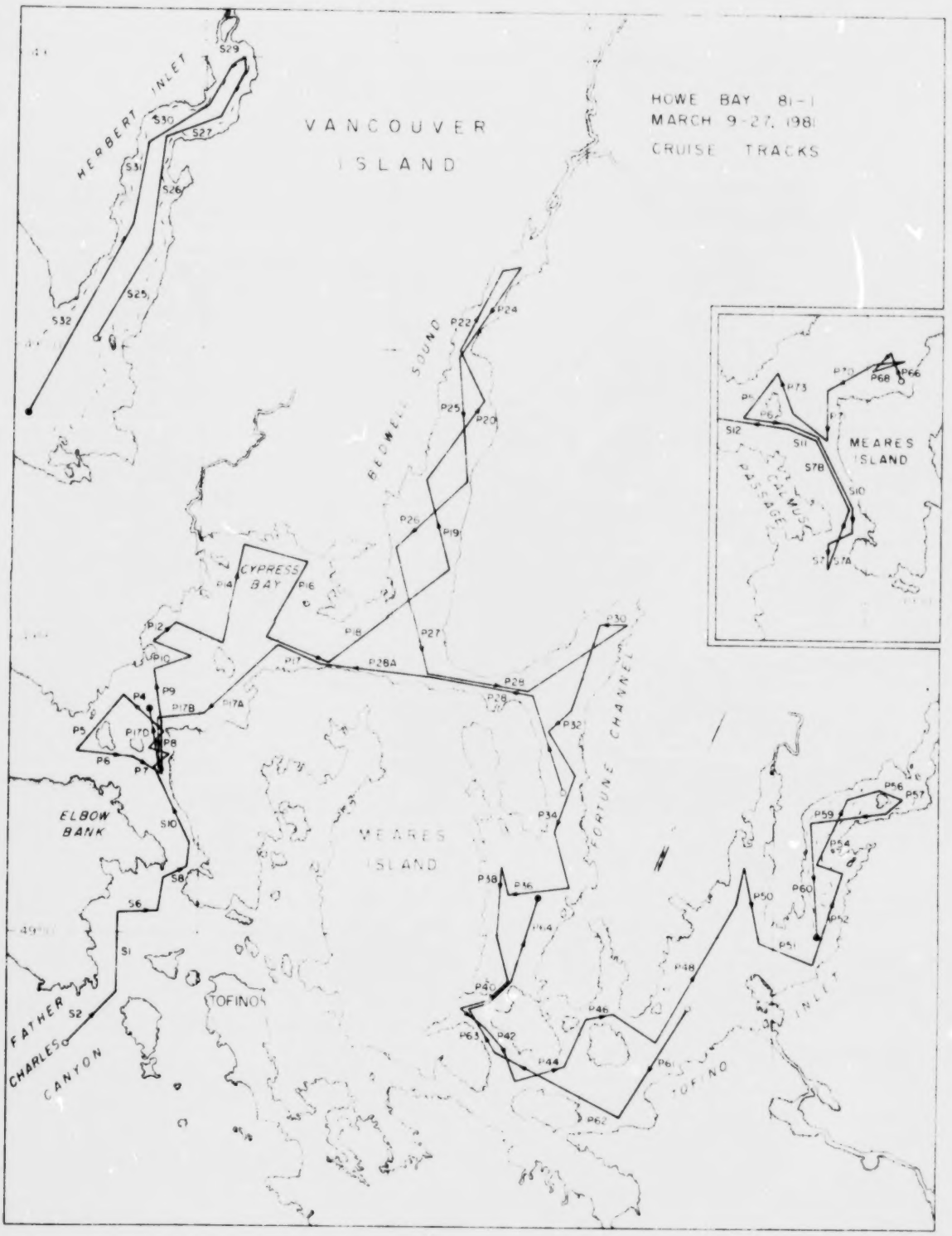

Fig. 13. Acoustic survey track-lines of the HOWE BAY in the southeast portion of Clayoquot Sound, March 9-27, 1981.

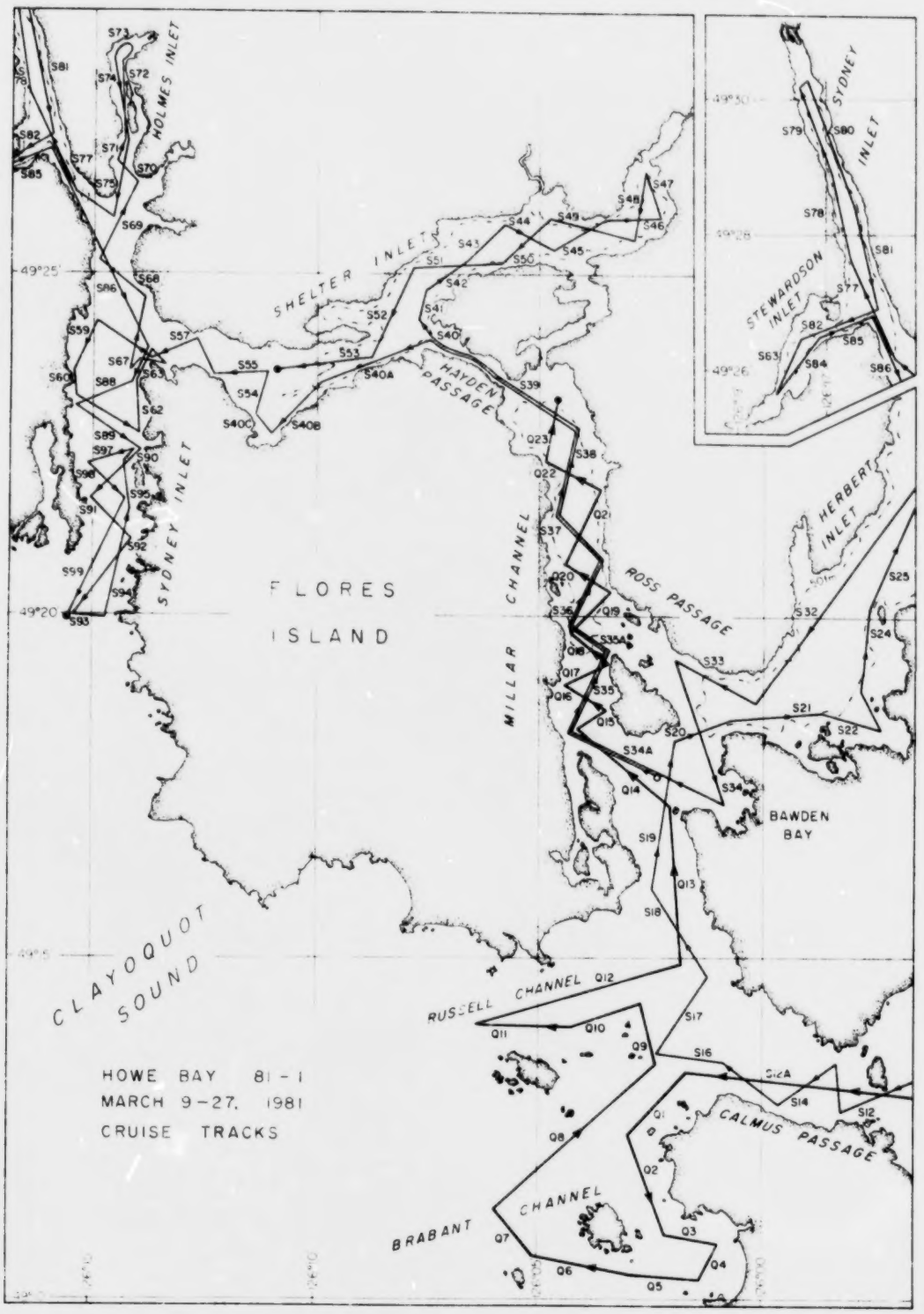

Fig. 14. Acoustic survey track-lines of the HOWE BAY in the northwest portion of Clayoquot Sound, March 9-27, 1981.

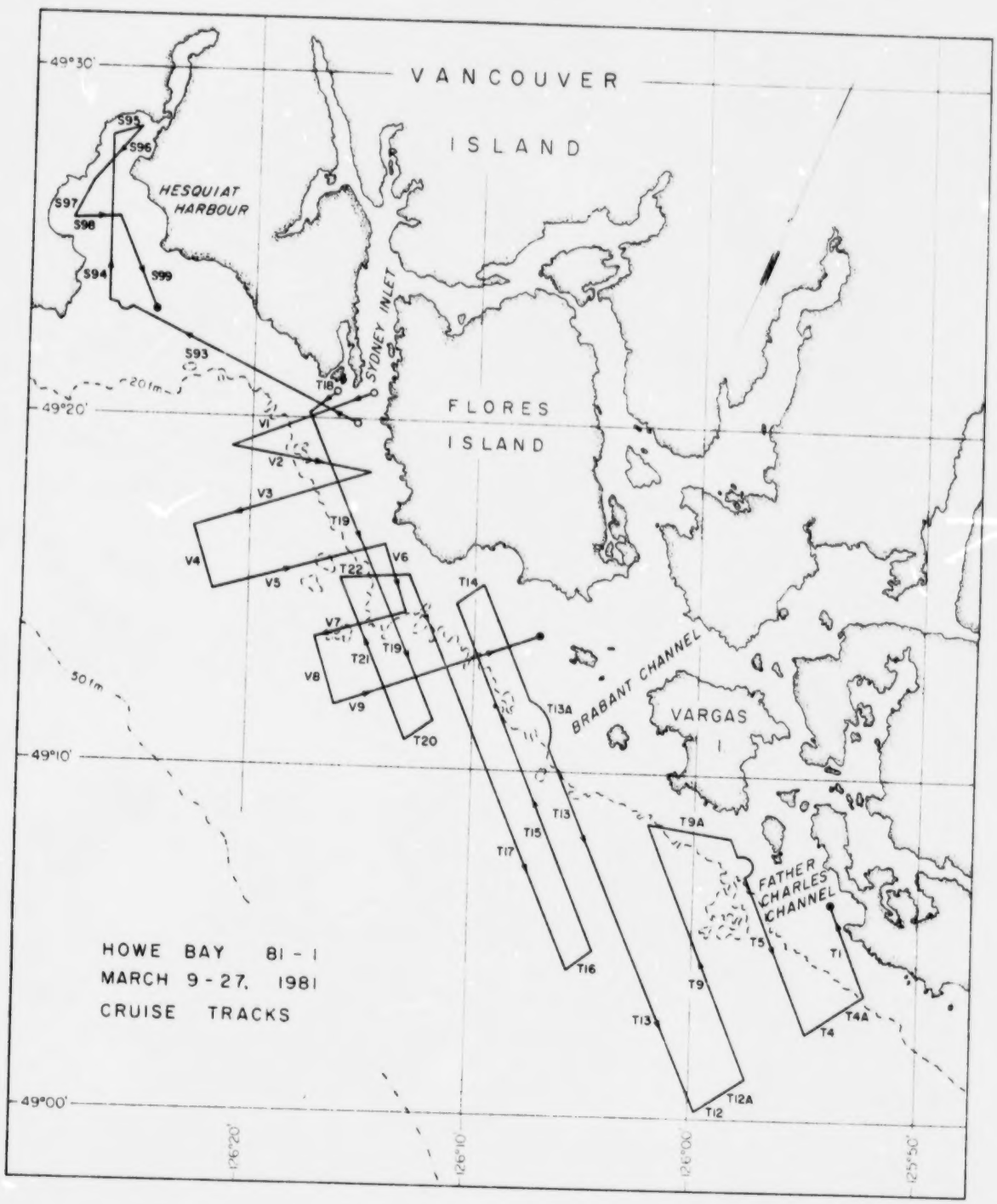

Fig. 15. Acoustic survey track-lines of the HOWE BAY near shore from Tofino Inlet to Hesquiat Harbour, March 9-27, 1981.

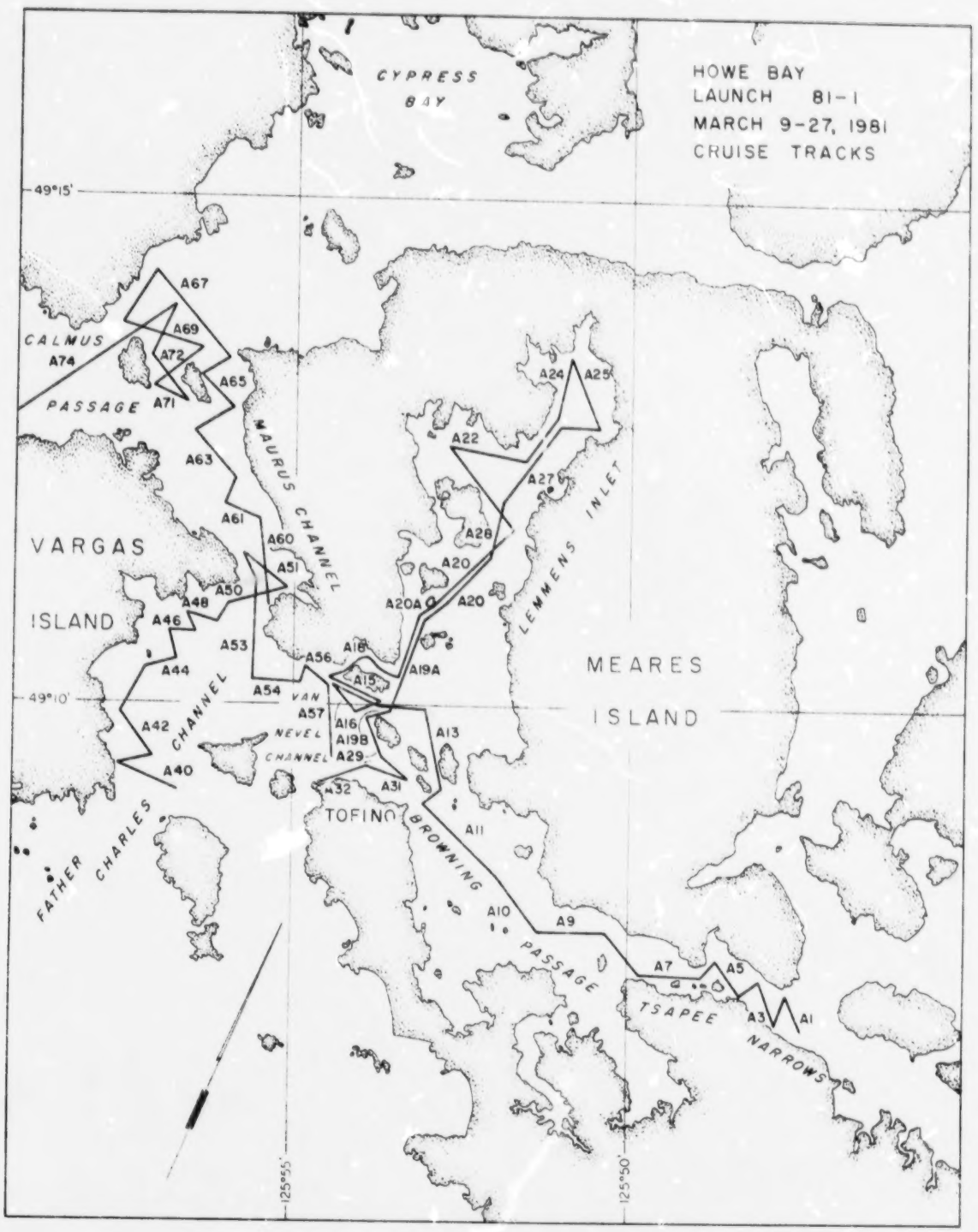

Fig. 16. Acoustic survey track-lines of the launch in the southeast portion of Clayoquot Sound, March 9-27, 1981.

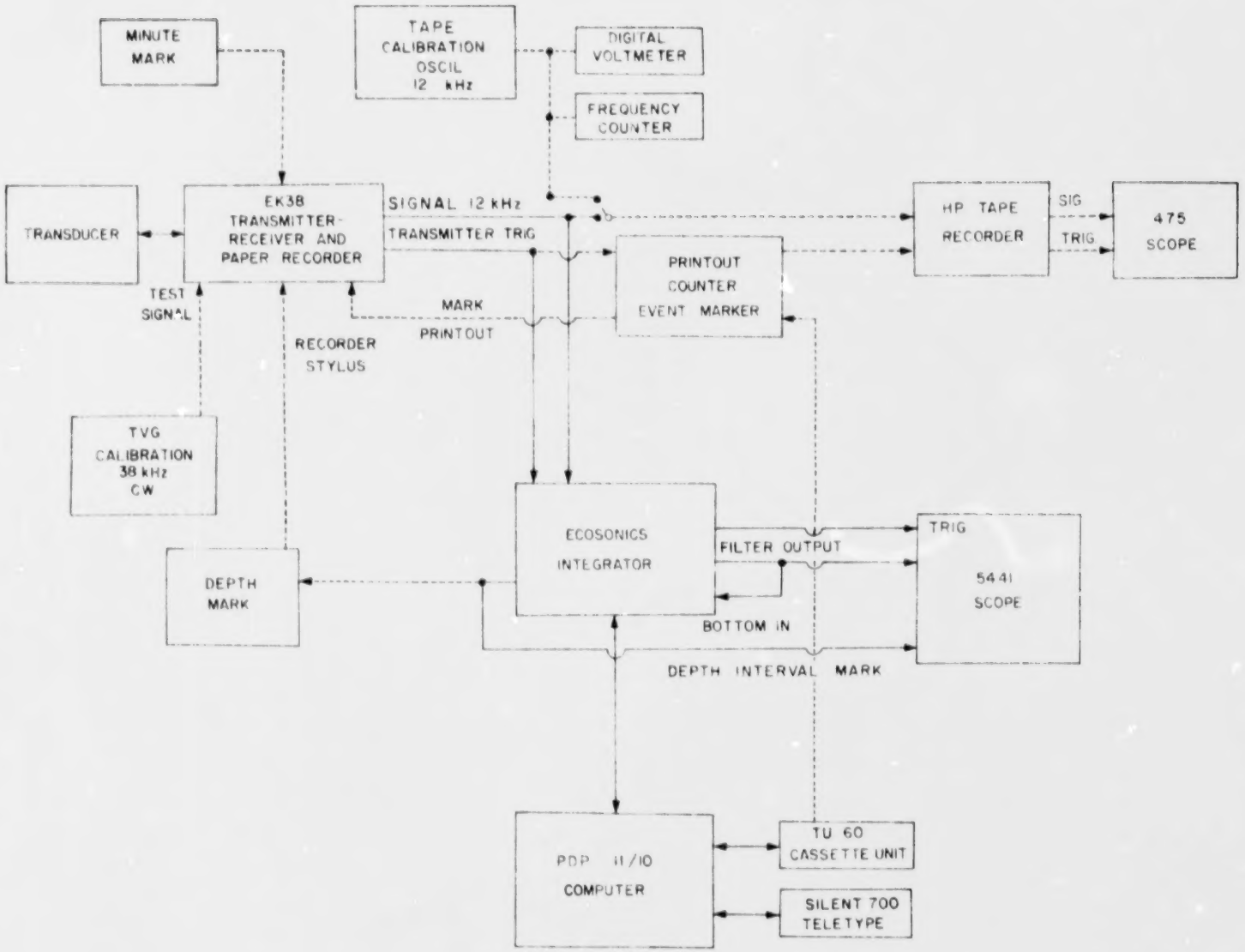

Fig. 17. Block diagram of the echo integration system, and auxiliary equipment used in the G. B. REED on the September and November, 1980, and March, 1981, cruises.

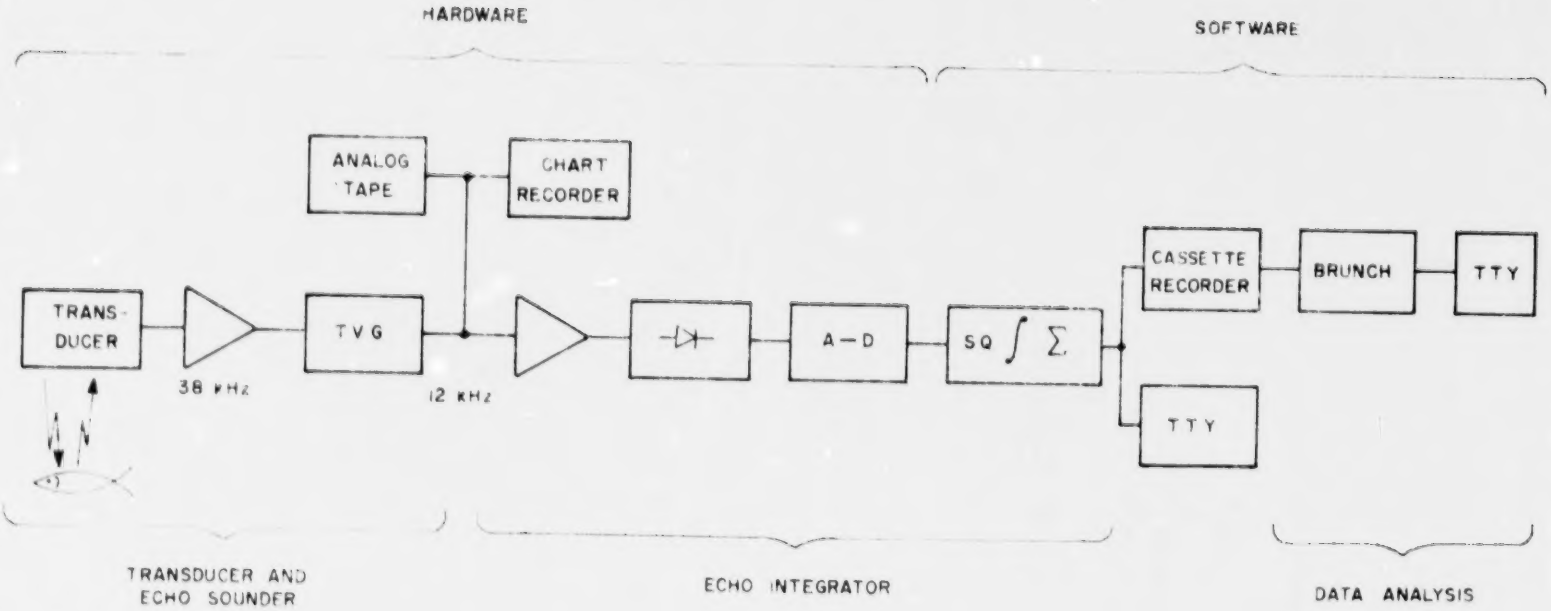

Fig. 18. Flow chart of the echo integration system used on the G.B. REED in September and November, 1980, and March 1981.

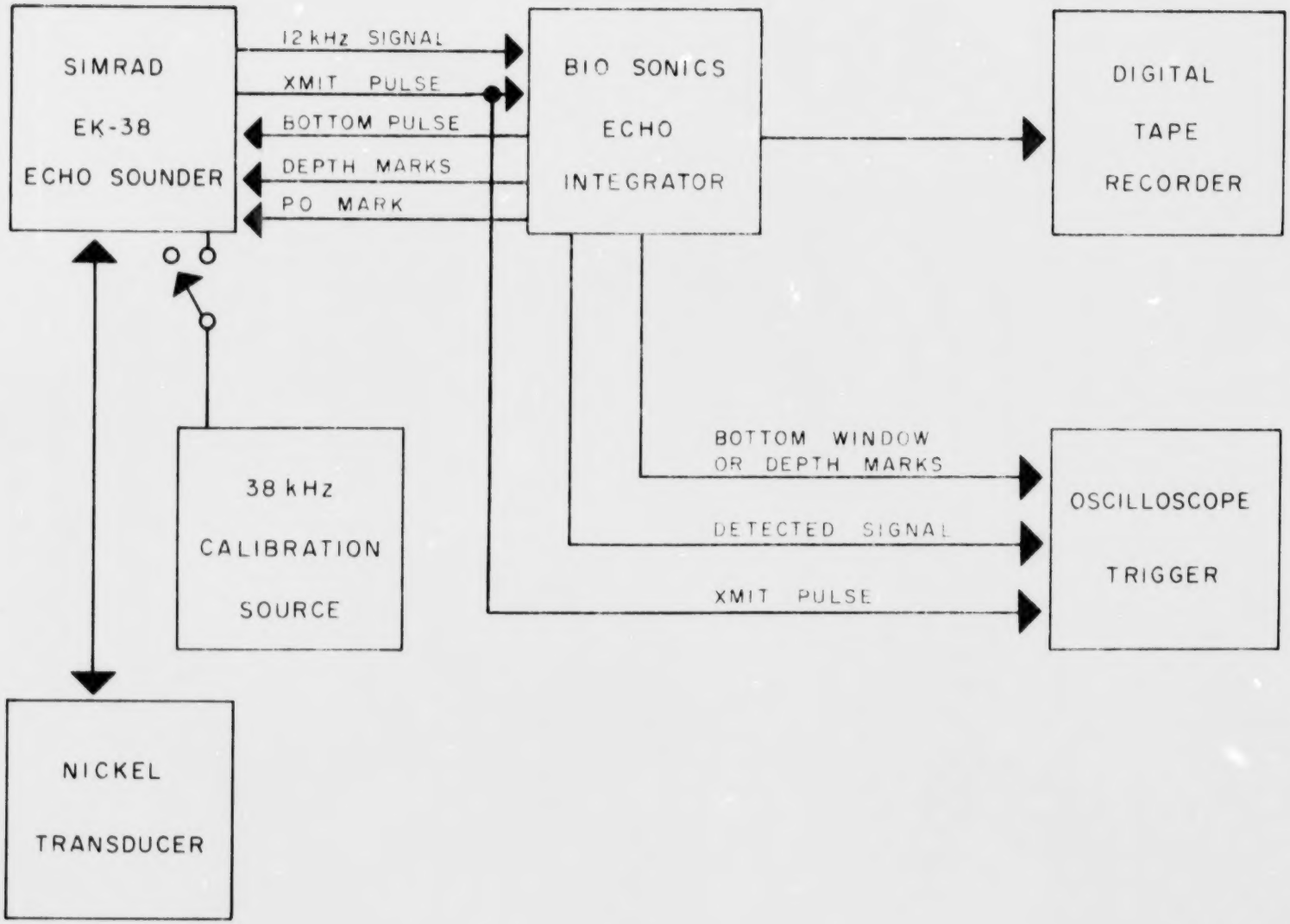

Fig. 19. Block diagram of the echo integration system used on the EASTWARD HO in November, 1980.

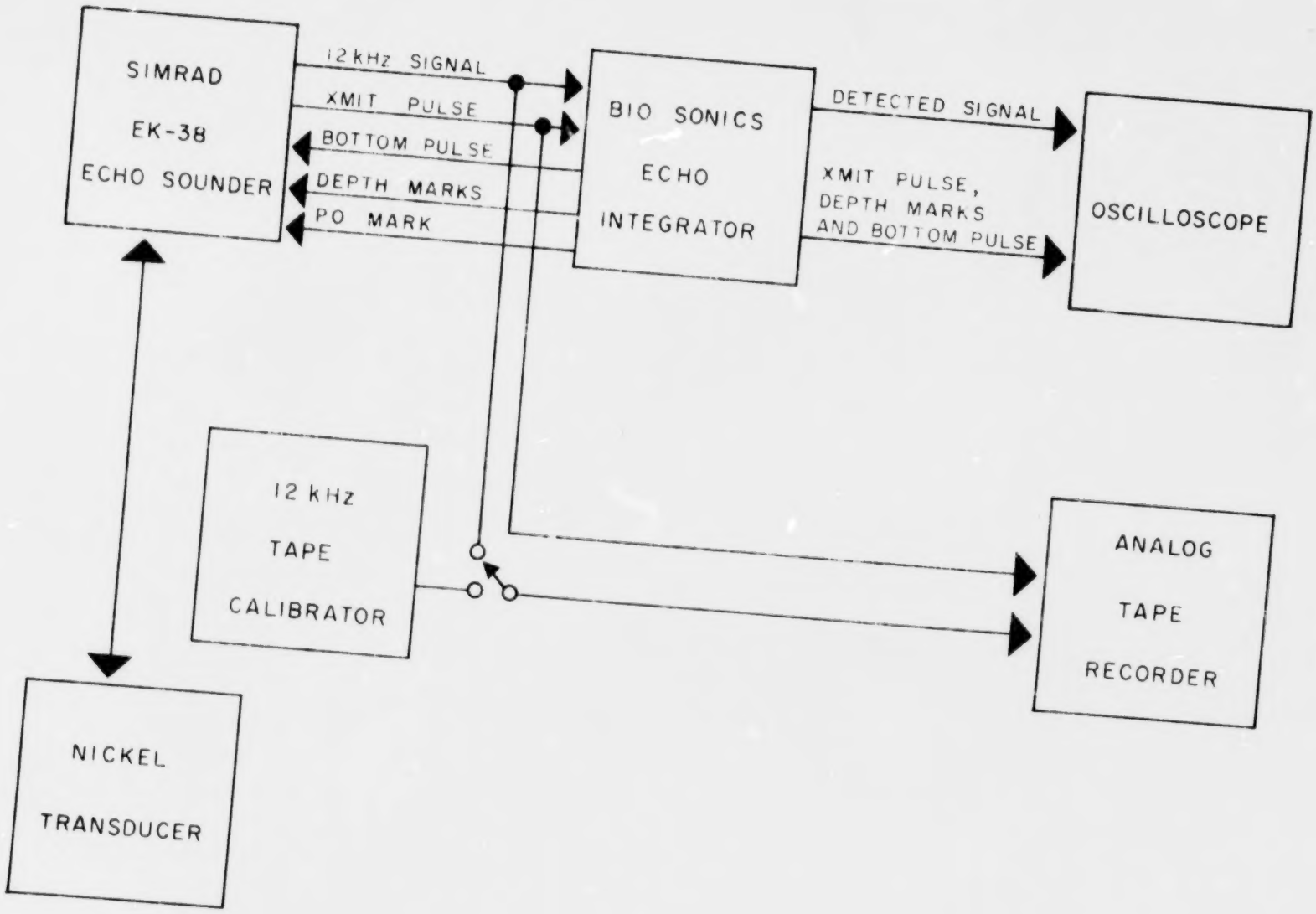

Fig. 20. Block diagram of the echo integration system used on the HOWE BAY in March, 1981.

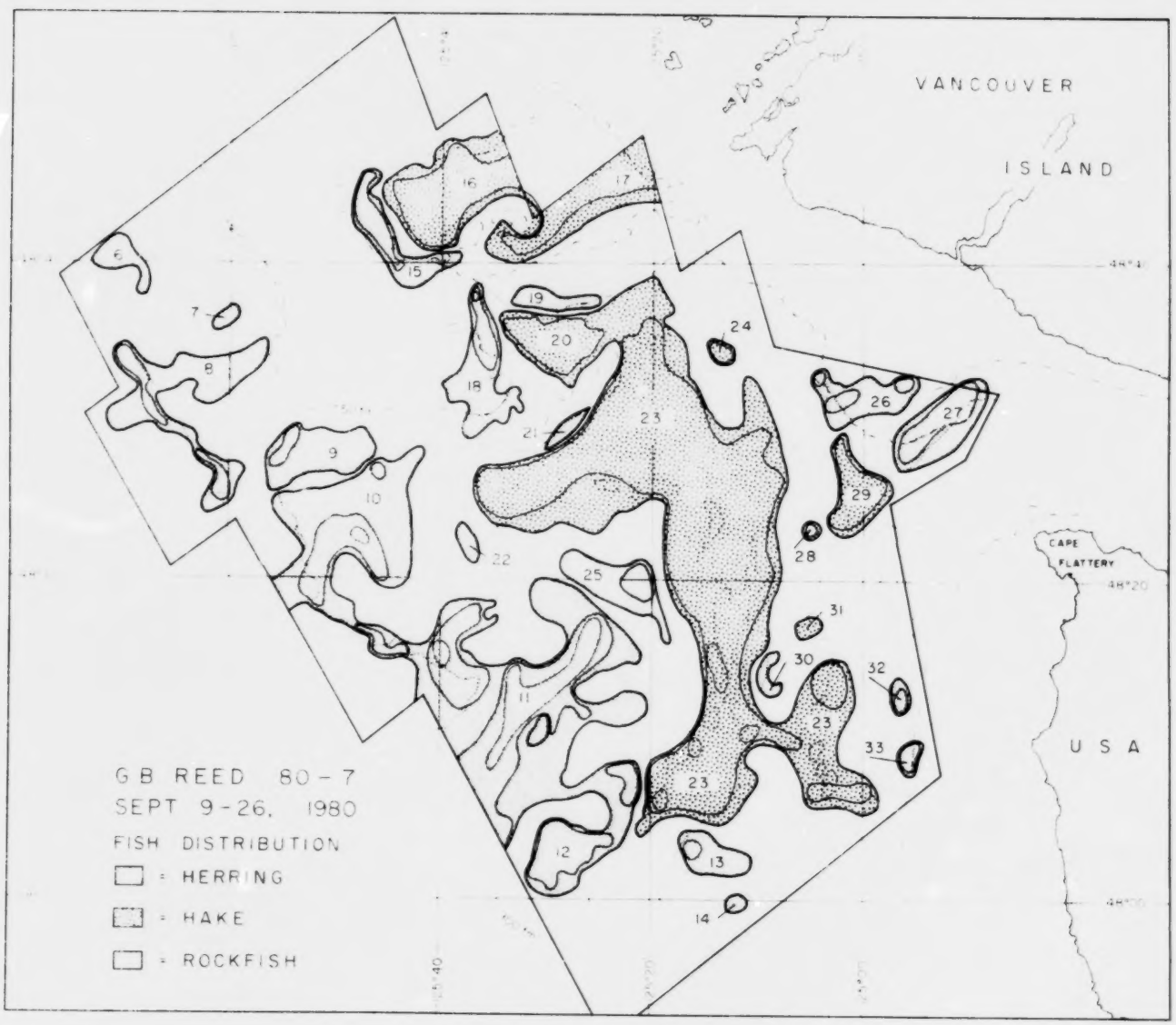

Fig. 21. Chart of the relative fish density from the Juan de Fuca Trench to Amphitrite Point, September 9-26, 1980.

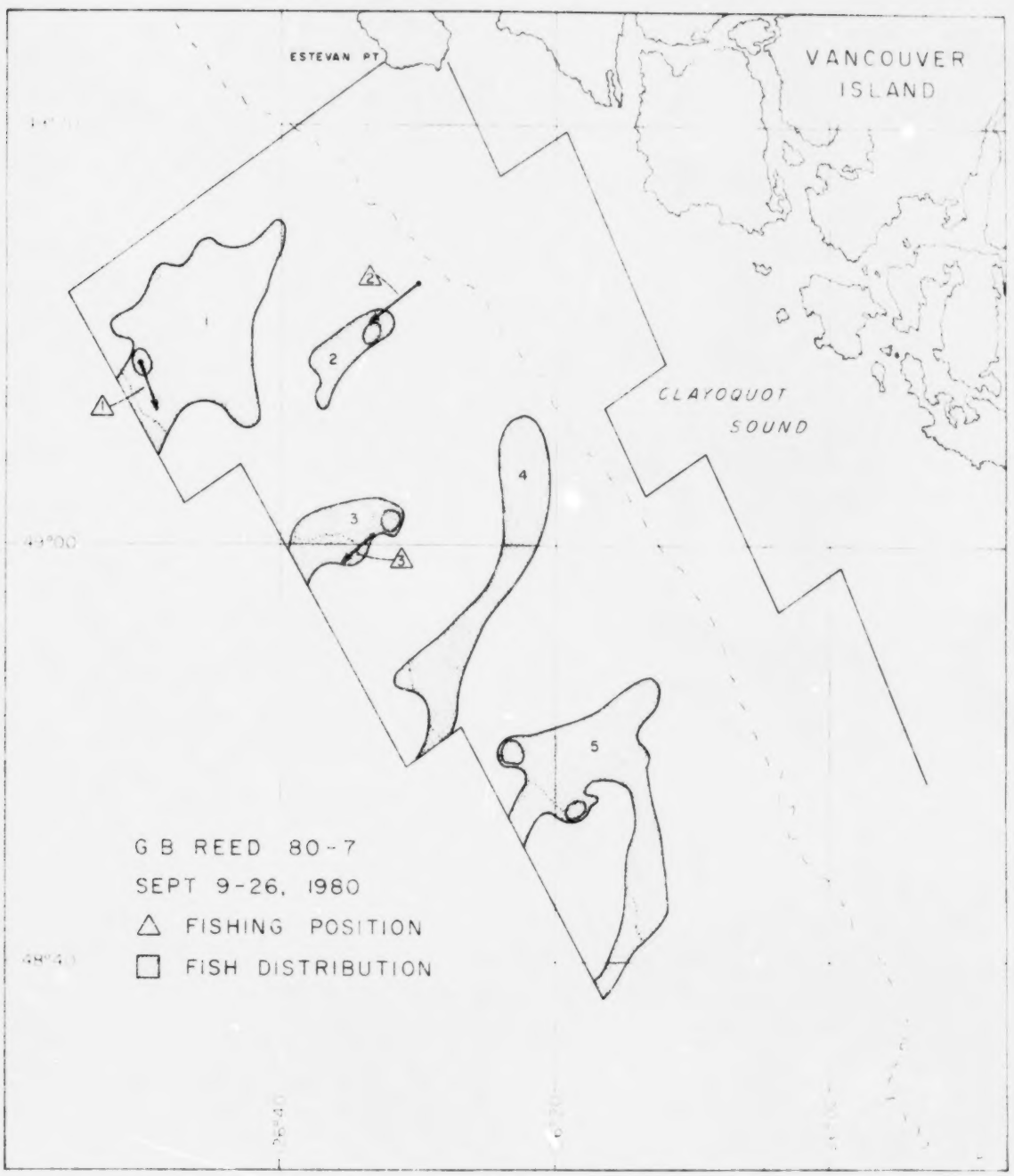

Fig. 22. Chart of relative fish density from Amphitrite Point to Estevan Point, September 9-20, 1980.

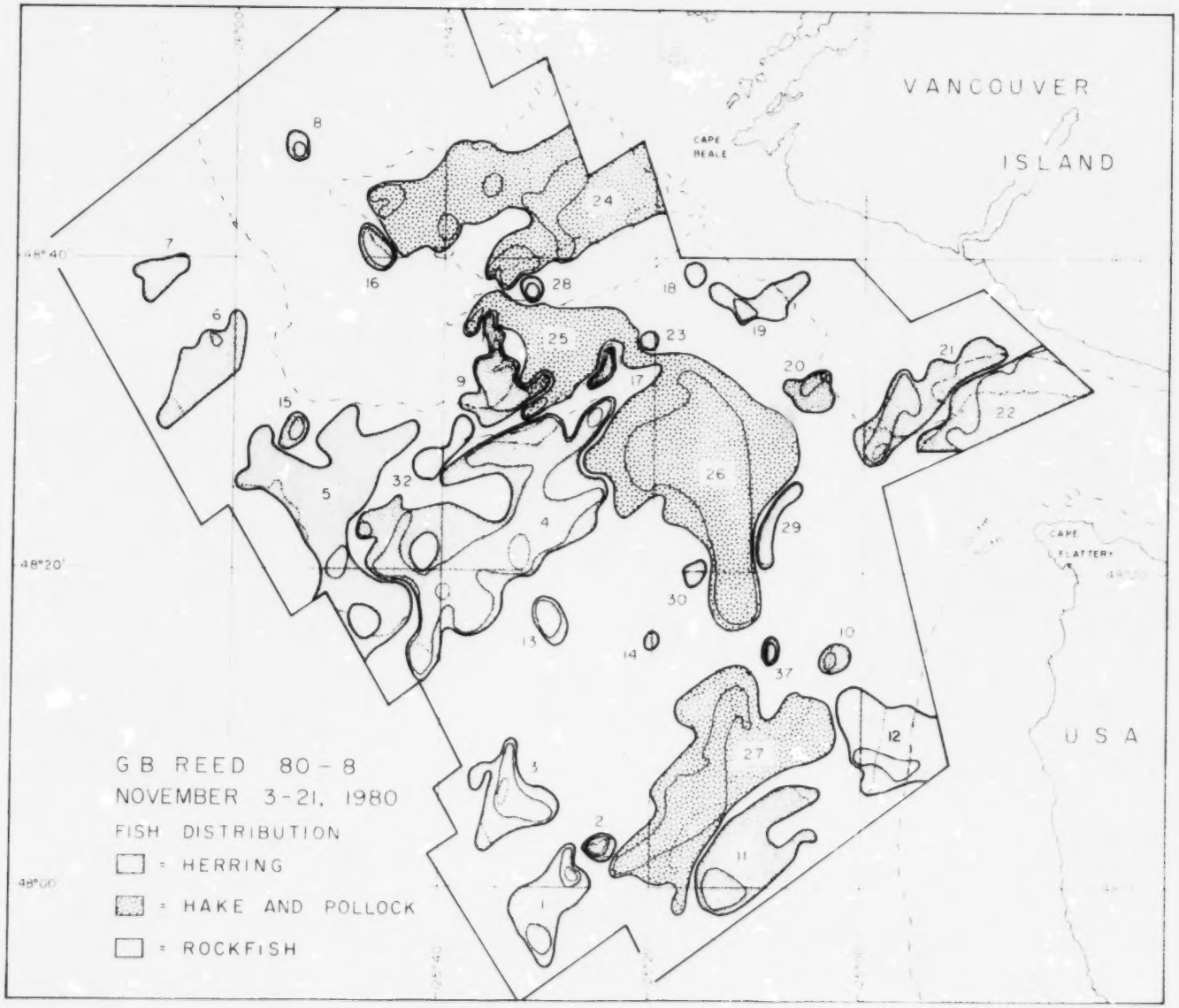

Fig. 23. Chart of relative fish density from the Juan de Fuca Trench to Amphitrite Point, November 3-21, 1980.

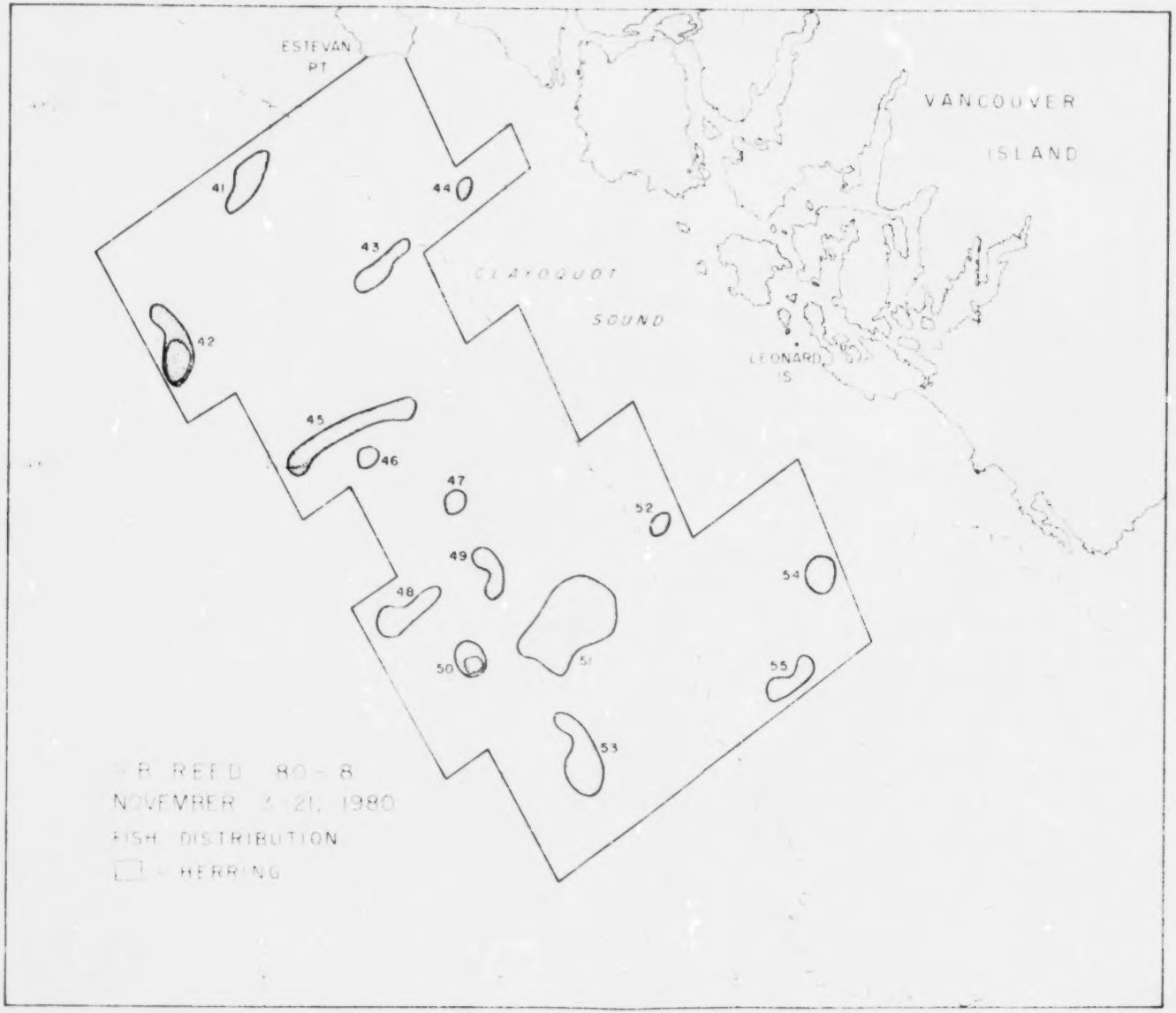

Fig. 24. Chart of relative fish density from Amphitrite Point to Estevan Point, November 3-21, 1980.

Fig. 25. Chart of relative fish density from the Juan de Fuca Trench to Amphitrite Point, March 9-27, 1981.

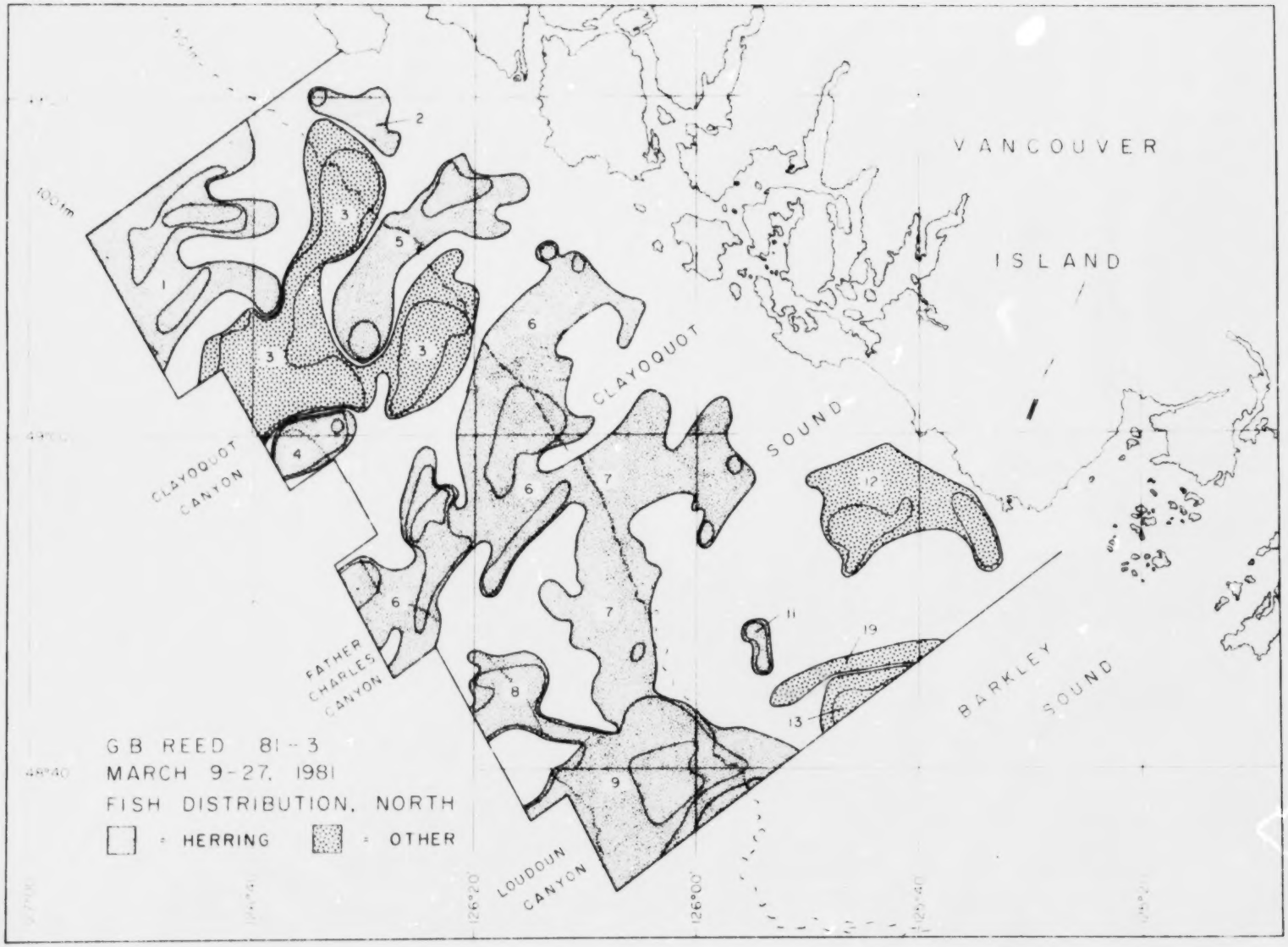

Fig. 26. Chart of relative fish density from Amphitrite Point to Estevan Point, March 9-27, 1981.

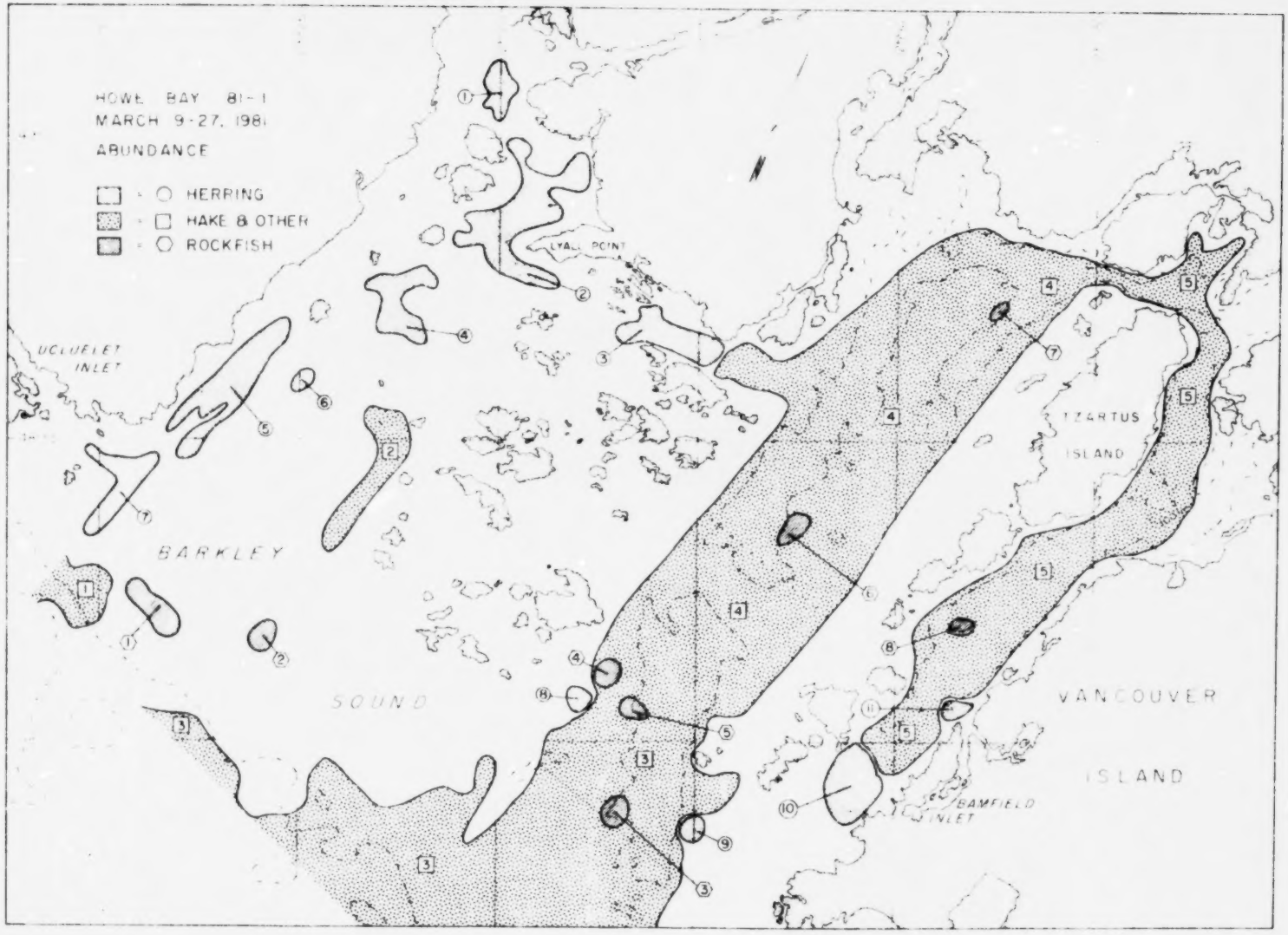

Fig. 27. Chart of relative fish density in Barkley Sound, March 9-27, 1981.

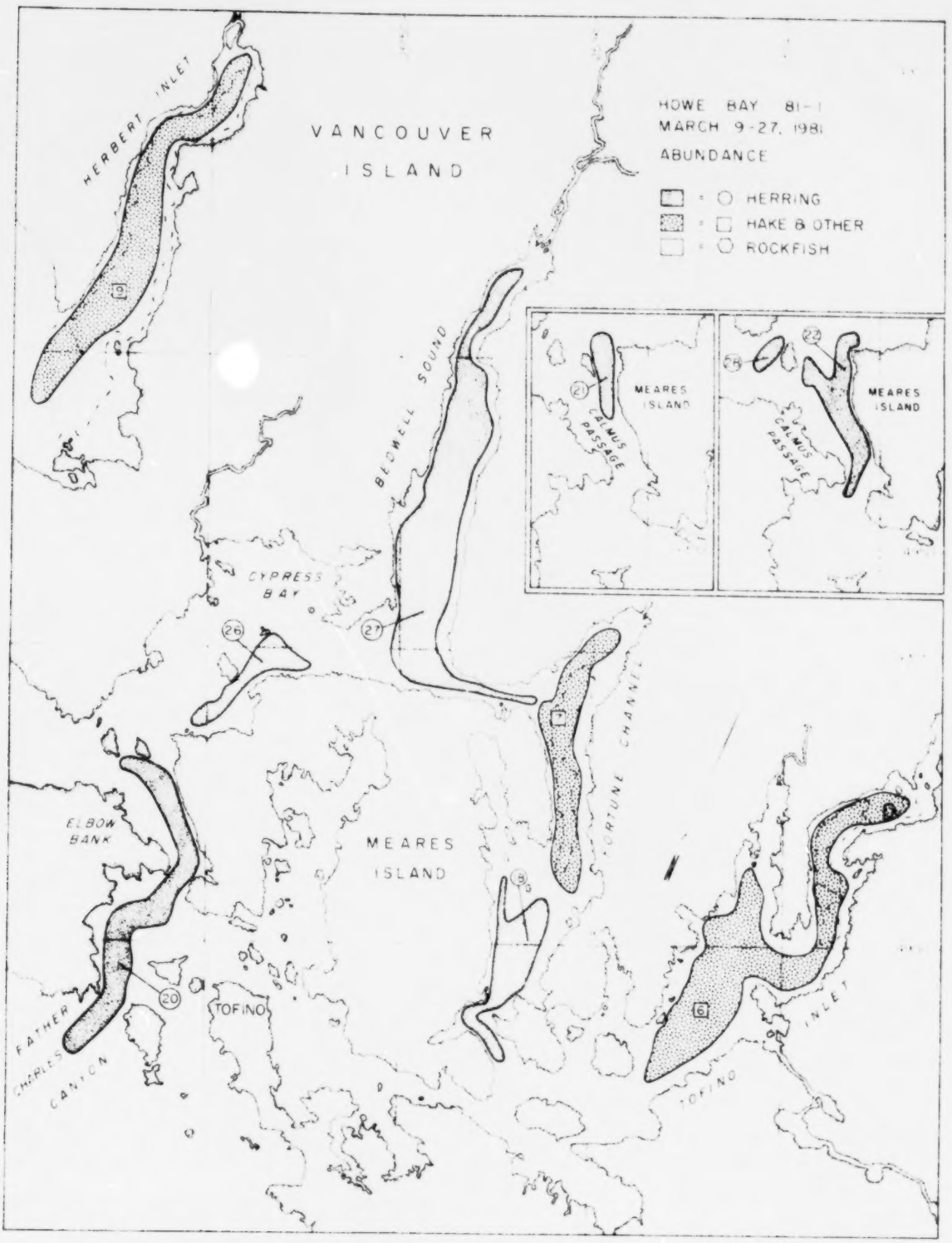

Fig. 28. Chart of relative fish density in the southeast portion of Clayoquot Sound, March 9-27, 1981.

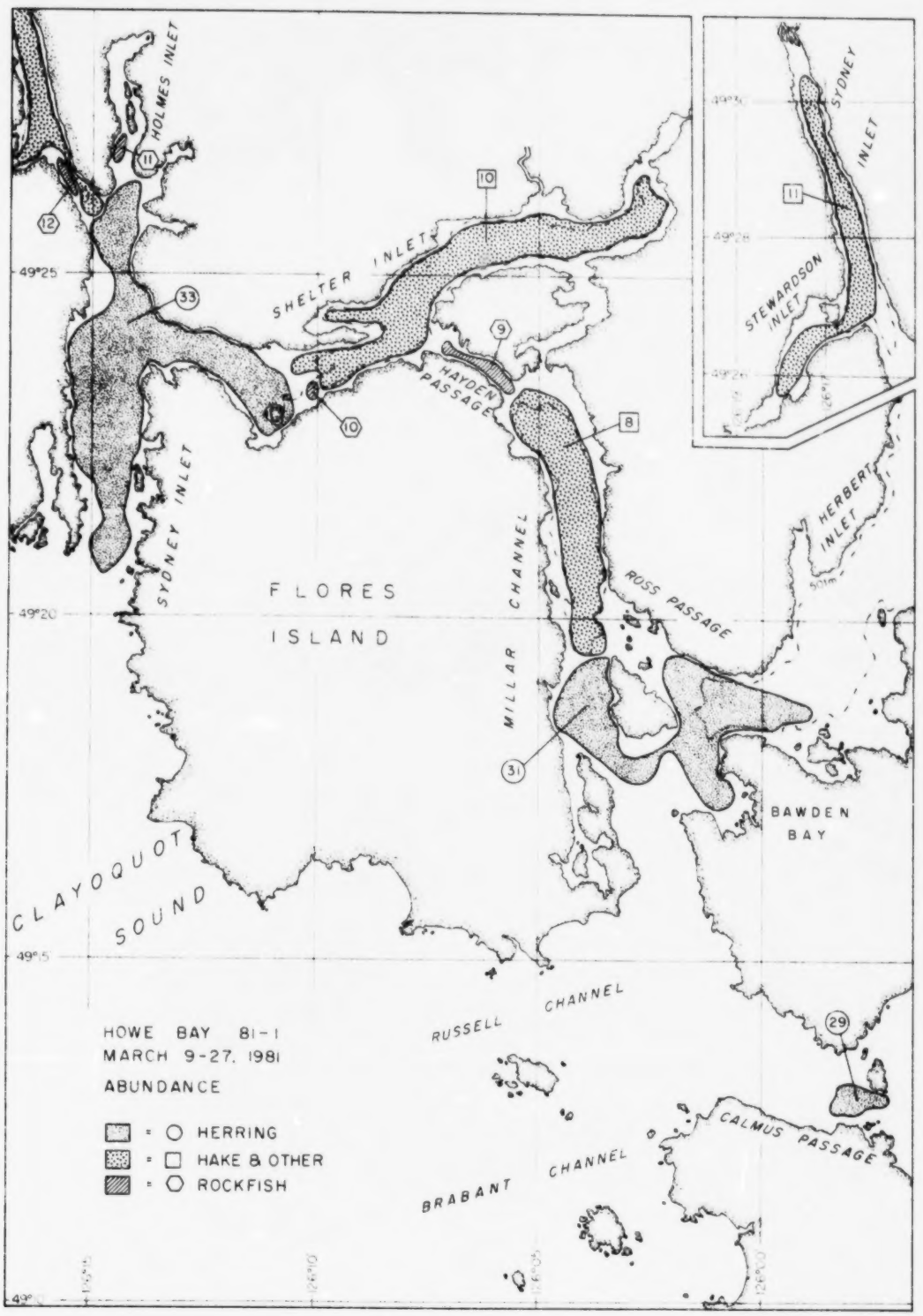

Fig. 29. Chart of relative fish density in the northwest portion of Clayoquot Sound, March 9-27, 1981.

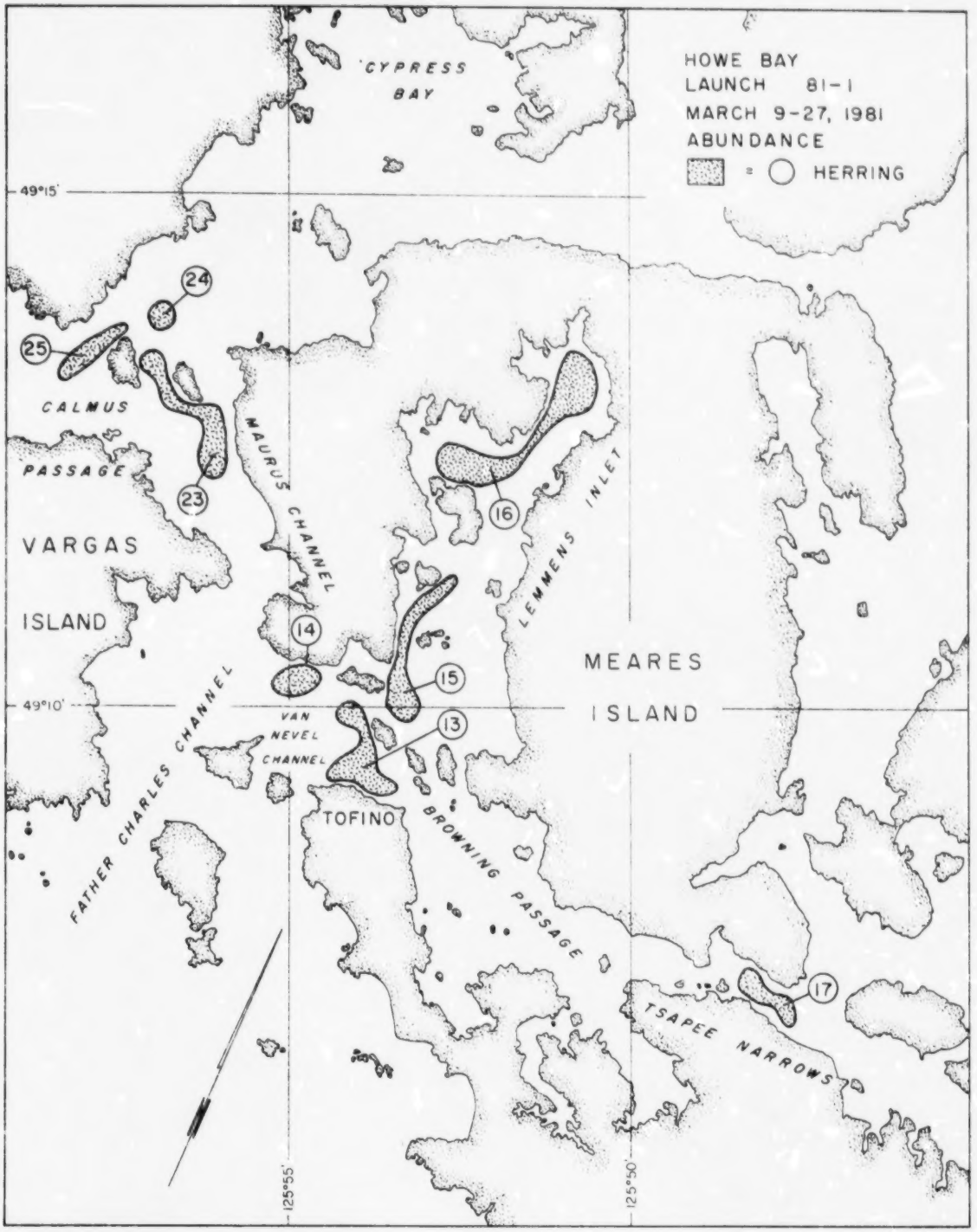

Fig. 30. Chart of relative fish density obtained by the launch survey of the shallow parts of the southeast portion of Clayoquot Sound, March 9-27, 1981.

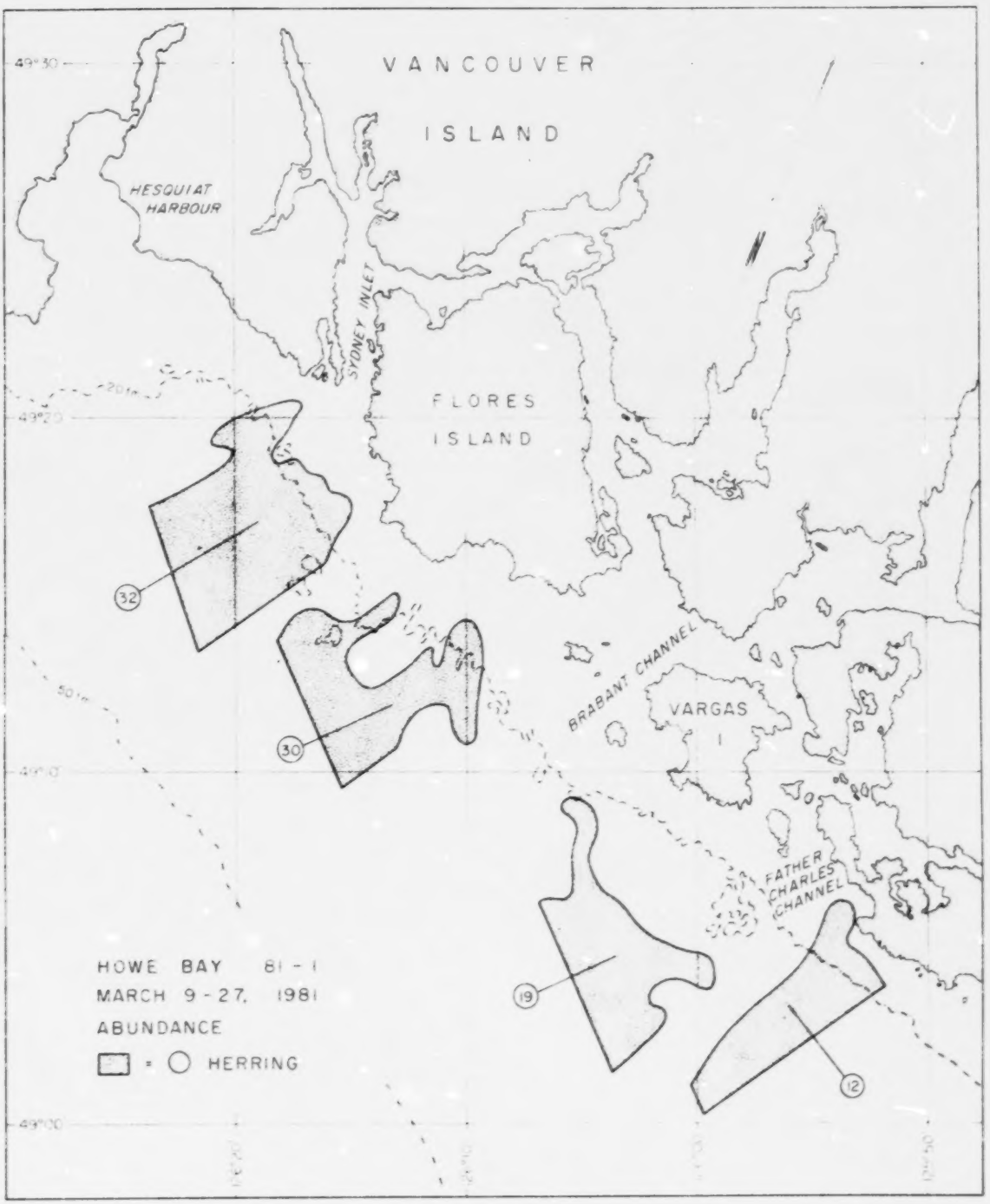

Fig. 31. Chart of relative abundance near shore from Tofino to Hesquiat Harbour, March 9-27, 1981.

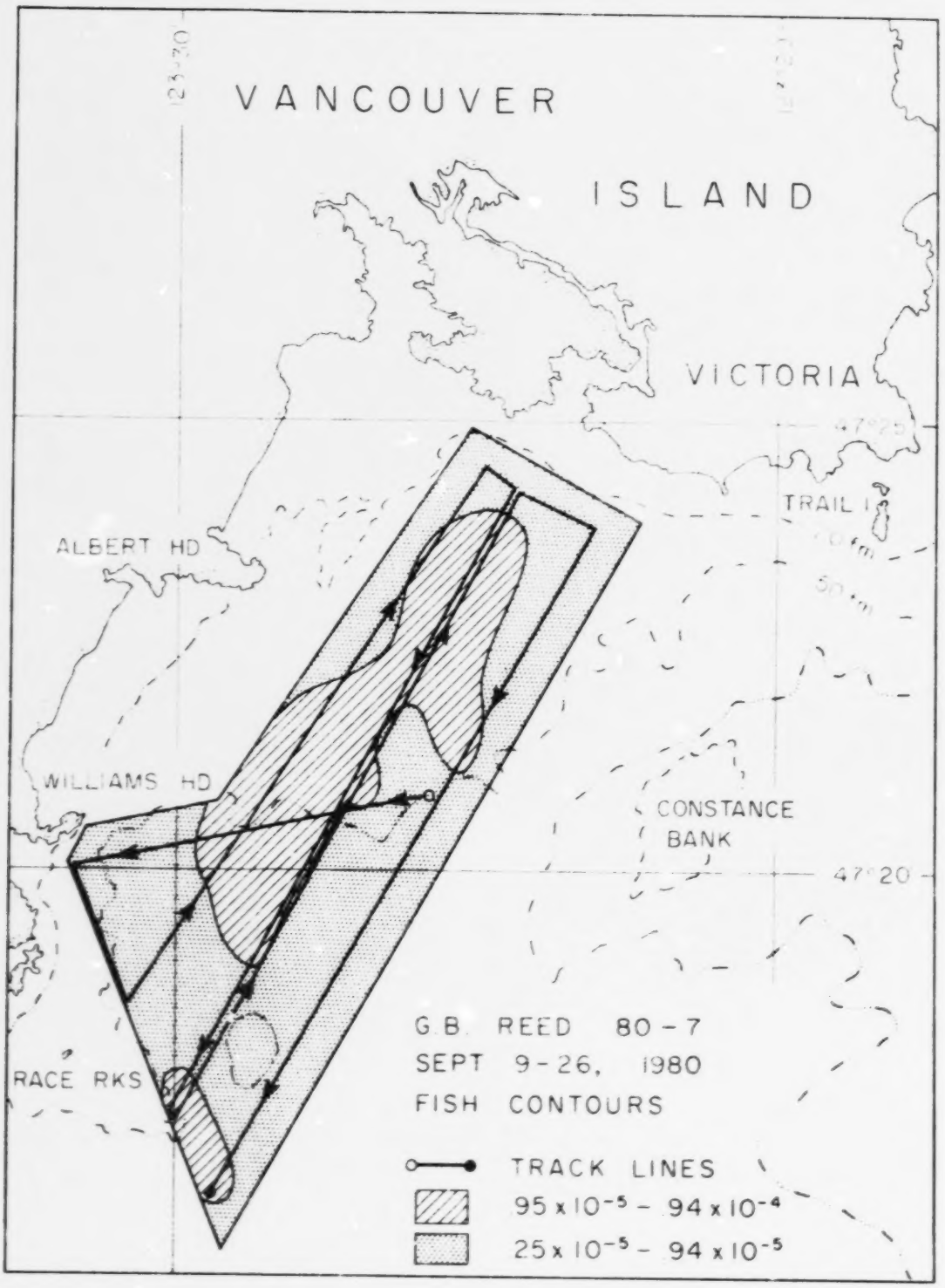

Fig. 32. Chart of relative fish density and track-lines off Victoria, Sept. 10, 1980.

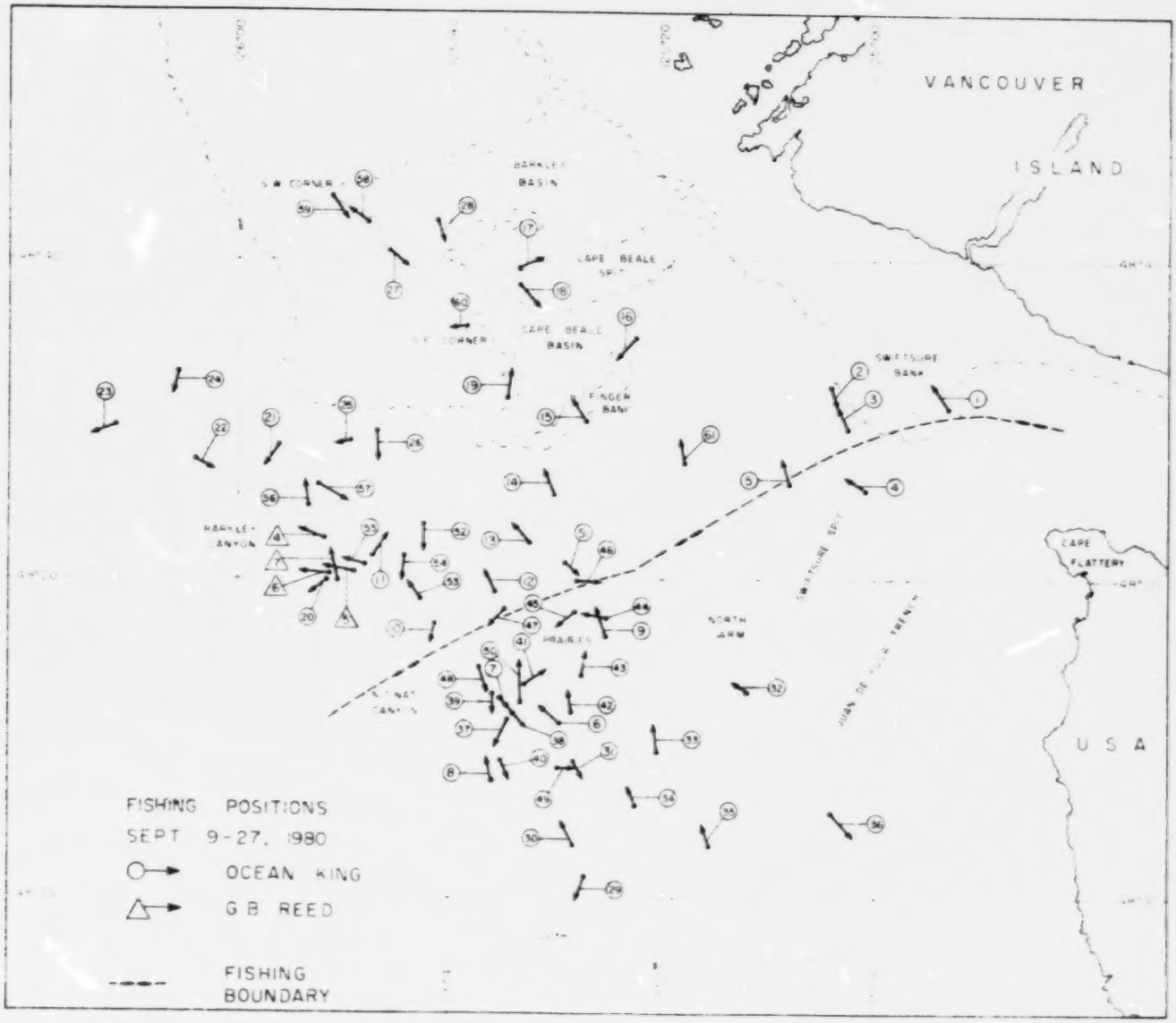

Fig. 33. Position of midwater trawl tows made by the OCEAN KING, off the west coast of Vancouver Island, Sept. 9-27, 1980.

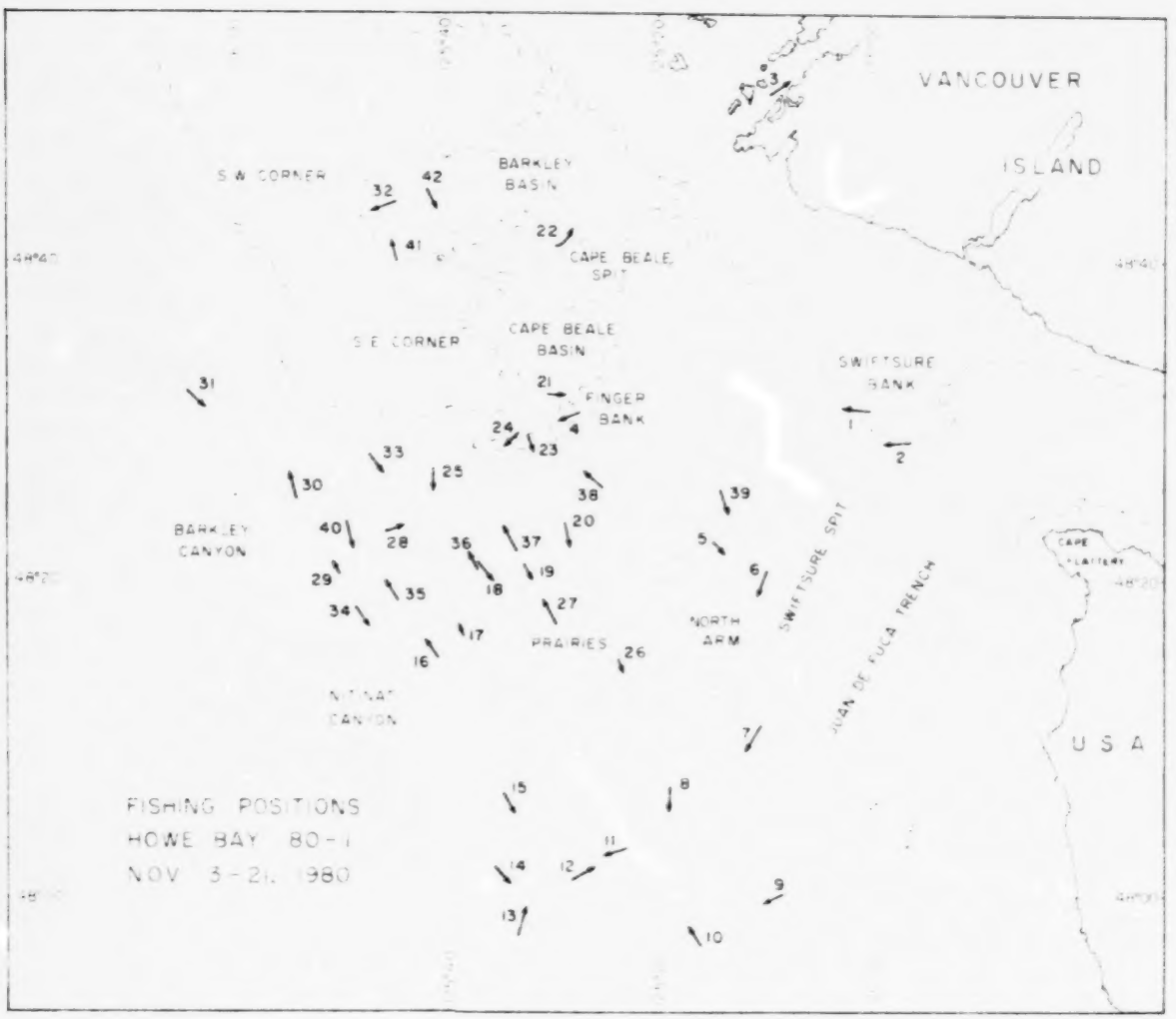

Fig. 34. Position of midwater trawl tows made by the HOWE BAY, off the west coast of Vancouver Island, Nov. 3-21, 1980.

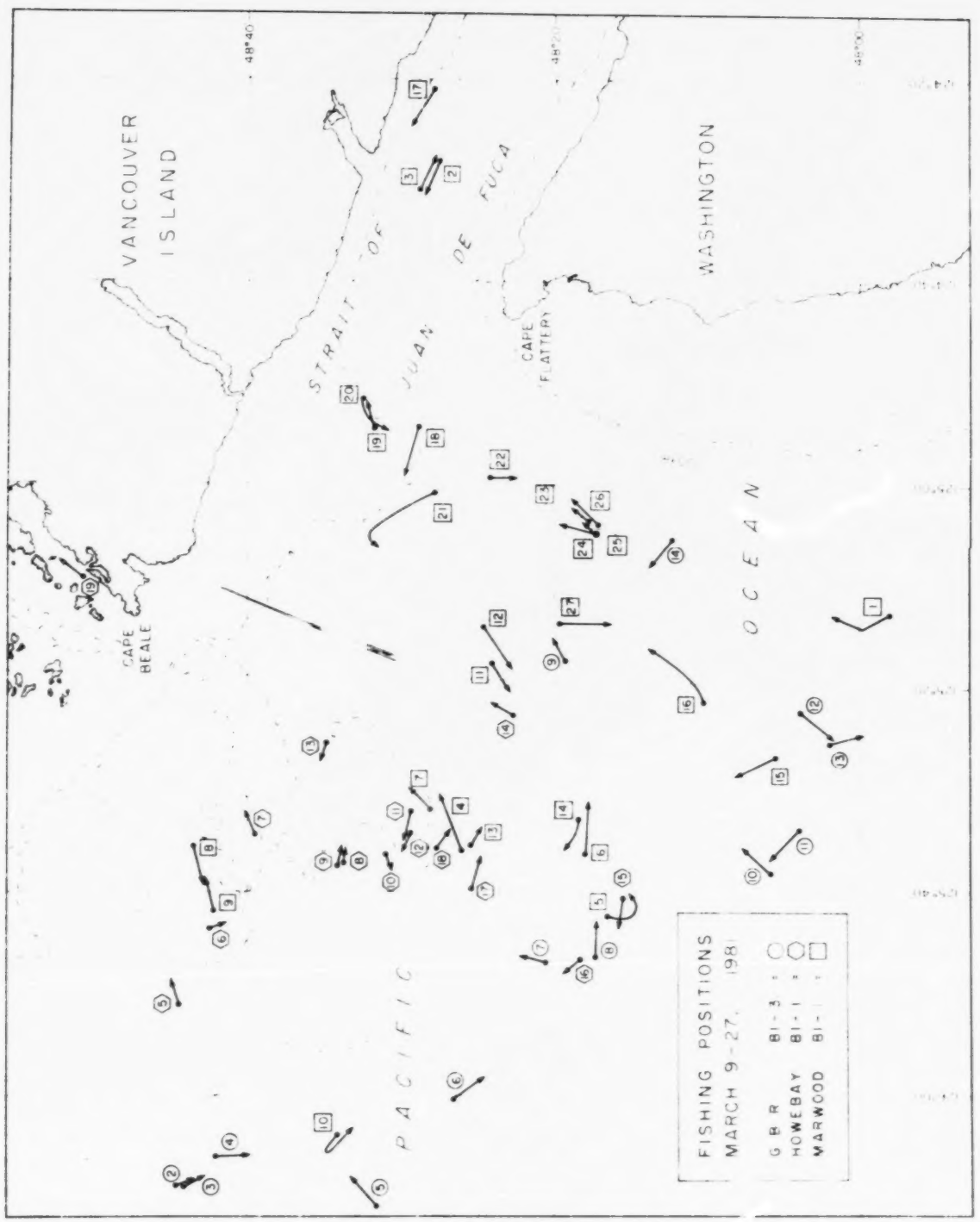

Fig. 35. Position of midwater trawl tows made by the MARWOOD, HOWE BAY, and G. B. REED off the west coast of Vancouver Island, March 9-27, 1981.

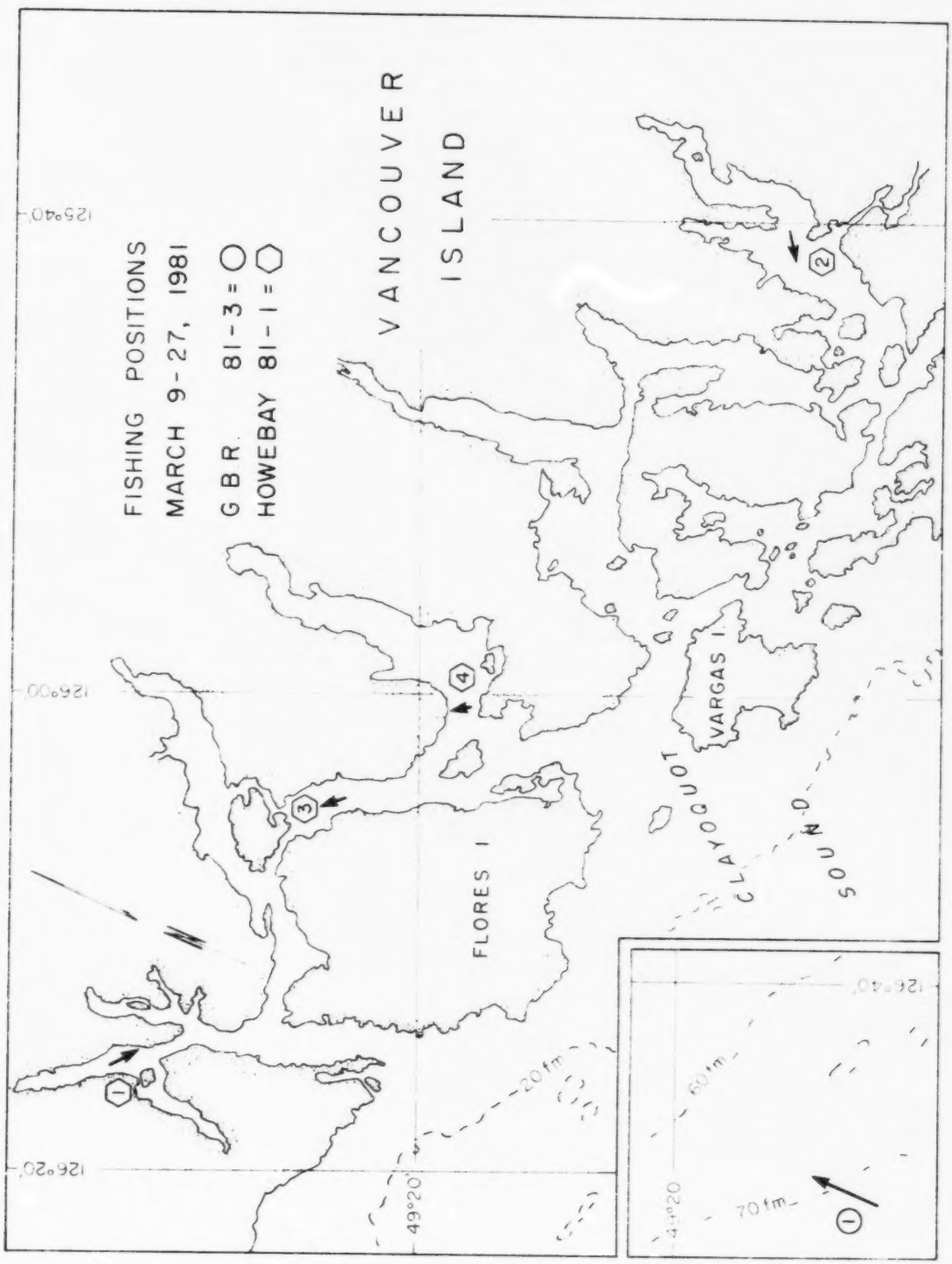

Fig. 36. Positions of midwater trawl in and off Clayoquot Sound, March 9-27, 1981.

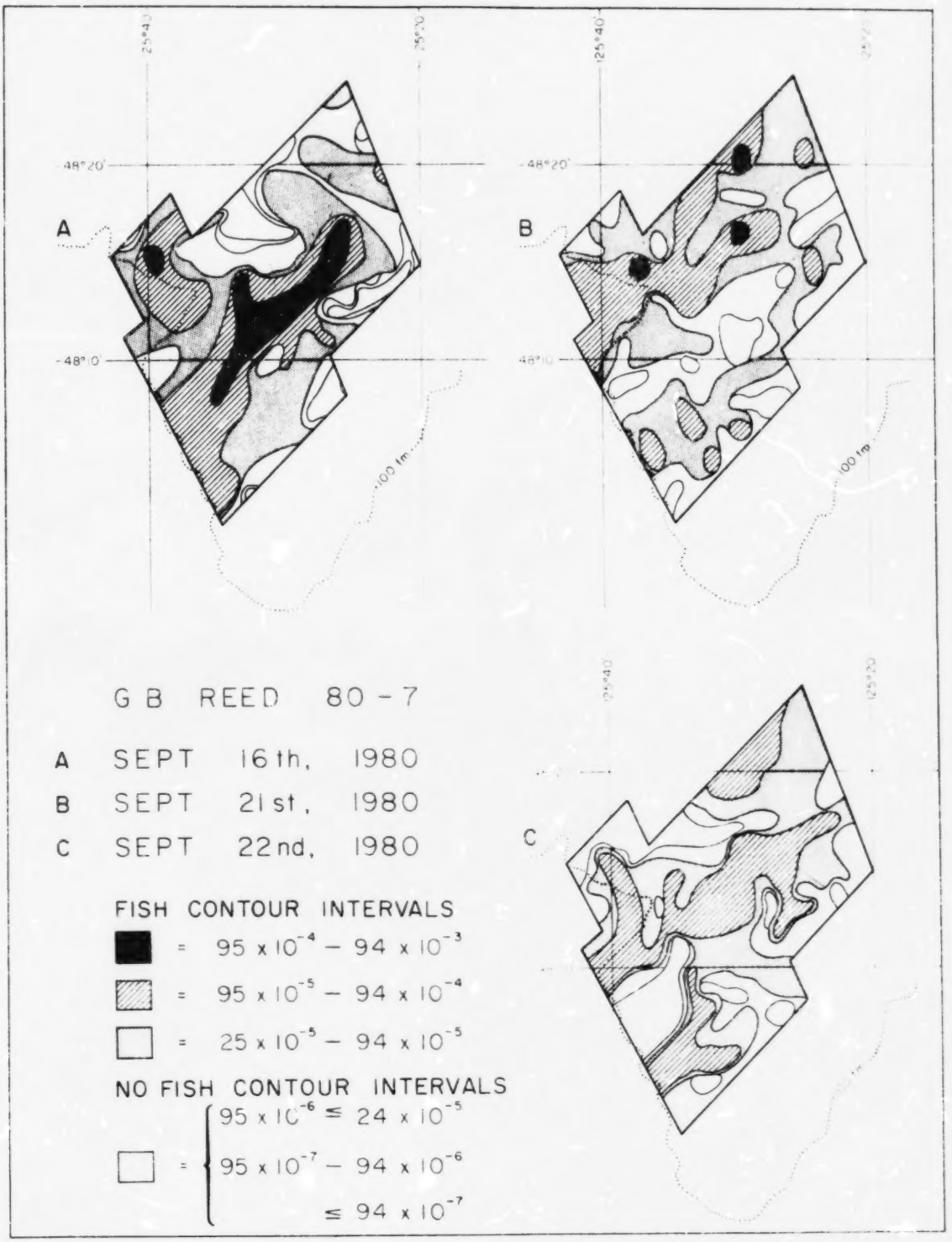

Fig. 37. Chart of relative fish density in the "experiment" area - A: on Sept. 16, 1980; B: on Sept. 21, 1980; and C: on Sept. 22, 1980.

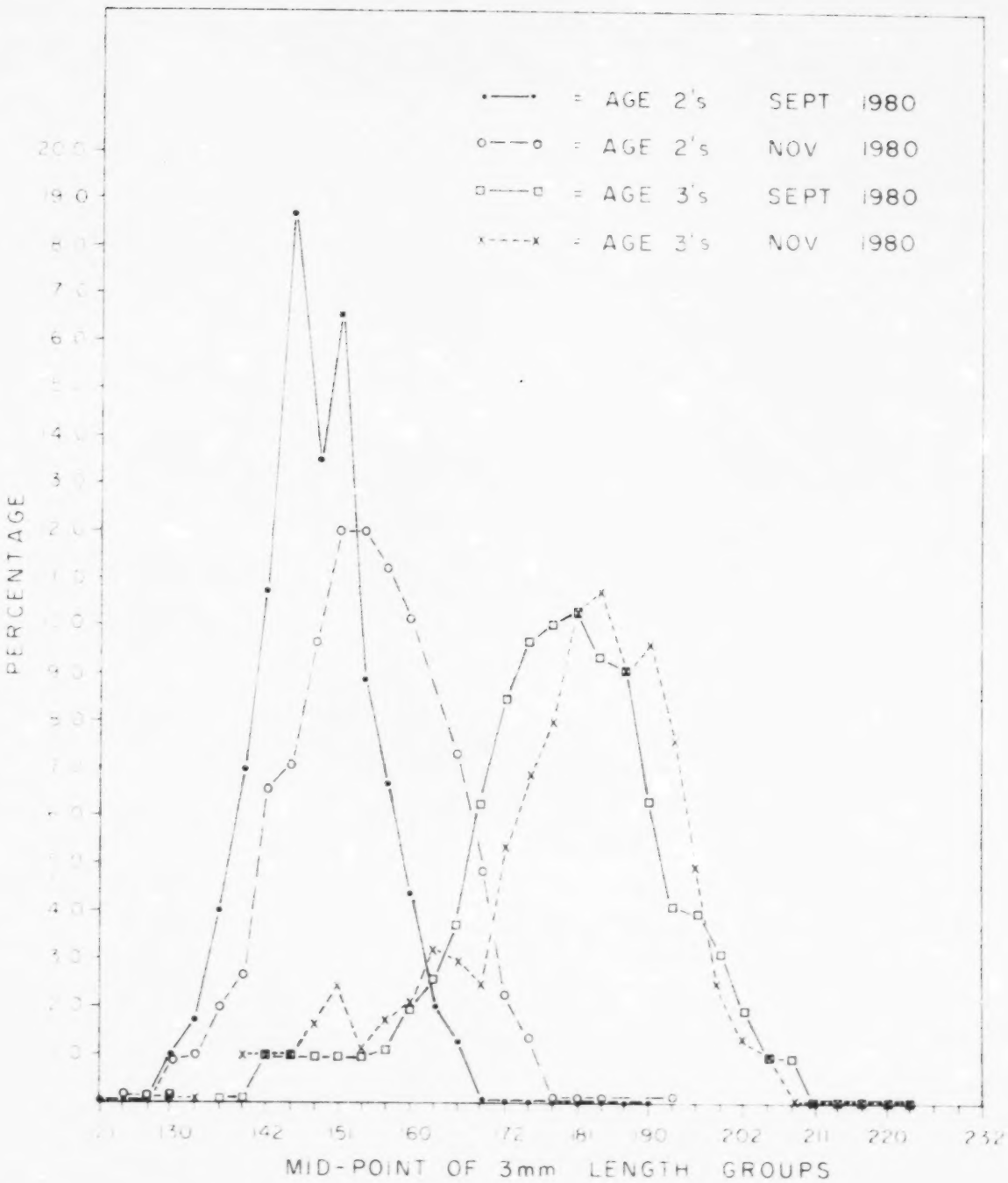

Fig. 38. Percentage length frequency distribution of herring of age 2 and age 3 in September and November, 1980, off the west coast of Vancouver Island.

APPENDIX

Appendix I. Hydroacoustic systems and values of constants used for biomass estimation, September, 1980, to March, 1981.

A. HYDROACOUSTIC SYSTEM

1. G. B. REED

The hydroacoustic system used on the G. B. REED was the same for all cruises, GBR80-7 (September), GBR80-8 (November), and GBR81-3 (March). It consisted of:

(a) Biosonics transmitter-receiver, model 101, 38 kHz, 1000 W.

(b) Simrad ceramic transducer, 38 kHz, with 15 x 30 cm^2 radiating face giving 13° x 7° beam between 3 dB points.
Serial No. S1698 used until November 6, when lost.
Serial No. S4318 used after November 6.

(c) Simrad EK38-S dry paper echosounder recorder.

(d) Ecosonics echointegrator.

(e) Digital Equipment Corporation PDP 11/10 computer.

(f) Digital Equipment Corporation TU60 cassette unit.

(g) Texas Instrument Silent 700 computer terminal.

(h) Hewlett-Packard 4-channel instrumentation tape recorder model 3960 F.

(i) Tektronix storage oscilloscope model RS403.

(j) Fathom Oceanology towed body Model 3.397-001.

(k) Transducer armoured towing cable, 95 m, 3 twisted, shielded pairs.

(l) Associated custom built units to produce calibration signals, timing signals to tape and chart recorder, and printout counter.

2. EASTWARD HO and HOWE BAY

The hydroacoustic systems used on the EASTWARD HO and HOWE BAY used the same major components but different in some of the auxiliary equipment and in the way the transducer was towed. On the EASTWARD HO the transducer was towed using a home-made wooden float-board, while on the HOWE BAY the transducer was mounted to an aluminum frame attached amidships to the port side of the vessel.

(a) Simrad EK38-A. Echosounder and recorder Model 81A. Serial No. 3025, 38 kHz, 1000 W used on EASTWARD HO and HOWE BAY.

(b) Transducers

(i) Simrad ceramic, Serial No. S4318, 15 x 30 cm^2 radiating face, 13° x 7° beam between 3 dB points. Serial No. S4318 used on EASTWARD HO to November 6, 1980.

(ii) Simrad nickel, Serial No. H21717, 15 x 30 cm^2 radiating face, 13° x 7° beam angle between 3 dB points. Used on EASTWARD HO and on HOWE BAY for 2 days. Found to be defective March 11, 1981.

(iii) Simrad nickel, Serial No. H20034, 15 x 30 cm^2 radiating face, 13° x 7° beam between 3 dB points used from March 12, 1981, on HOWE BAY.

(c) Transducer armoured towing cable, 30 m, 3 twisted, shielded pairs - used on EASTWARD HO and HOWE BAY.

(d) Biosonics echointegrator model 210. Used on EASTWARD HO and HOWE BAY.

(e) Kennedy digital tape recorder, Model 9000. Used on EASTWARD HO and HOWE BAY.

(f) Tektronix dual trace oscilloscope, Model 475, used on EASTWARD HO and HOWE BAY.

(g) Hewlett-Packard signal generator used on EASTWARD HO and HOWE BAY.

(h) Tandberg audio tape recorder Model 3041X used on HOWE BAY.

8. SYSTEM CONSTANTS

The model for the hydroacoustic biomass estimation was the same as used by Taylor and Kieser (1980, 1981), with the addition of an extra term to account for losses produced by the shell of the towed body. The constants used in the G. B. REED'S system on all three cruises are given below. Similar constants have not been provided for the EASTWARD HO'S or the HOWE BAY'S systems, since, because of a series of problems mainly with the transducers, the results are regarded as only qualitative.

1. Source level (TL)

Ceramic transducer S1698 222.2 dBμPa/m; 222.6 dBμPa/m
Ceramic transducer S4318 222.3 dBμPa/m.

2. Voltage response (VR)

Ceramic transducer S1698 - 97.4 dBV/μPa, TVG100; -97.7 dBV/μPa, TVG100
Ceramic transducer S4318 - 99.1 dBV/μPa, TVG100.

3. Receiver gain (RG): - 12.00 dB.

4. Shell loss (SL): - 1.1 dB.

5. Spreading and absorption loss at reference depth (R100).

   R100: $-(2\alpha 100+20\log 100) = -41.98$ dB

6. Beam factor (Ψ): - 17.55 dB.

7. Depth slice (ΔR or CTAU):

   $10 \log \frac{c\tau}{2} = 10 \log \frac{1500}{2} \times 0.006 = -3.47$ dB

8. Bandwidth factor (BW):

   $10 \log \frac{\text{⎍}}{\text{⎍}} = -0.96$ dB

$$I_{mn} = TL + VR + RG + SL + R100 + \Psi + CTAU + BW + \overline{TS} + \overline{RO}$$

$$I_{mn} = 124.5^{a} - 12.0 - 1.1 - 41.98 - 17.55 - 3.47 - 0.96 + \overline{TS} + \overline{RO}$$

$$I_{mn} = 47.44 + TS + RO$$

Where TS = Target strength in dB/kg, and

RO = average fish density ($\frac{No.}{m^3}$) in a layer $\frac{c\tau}{2}$ thick at distance r = $\frac{c\tau}{m^3}$ from the transducer and limited to the side by the transducer's beam width.

C. TVG CORRECION FACTORS

The G. B. REED'S hydroacoustic system employed a Biosonics echosounder. This instrument has an accurate TVG. Consequently no secondary corrections are required.

D. TARGET STRENGTH VALUES

Our equipment cannot be used to measure target strength in situ, consequently these values are taken from the literature (Appendix Table 1). Even after critical evaluation, published values show a

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[a]124.5 is the average of TL+VR for the two calibrations of transducer S1698. The first calibration was in May, 1980, the second in October, 1980.

considerable spread (of the order of 1dB). Appendix Fig. 1 is a plot of target strength (dB) normalized by fish weight (TS/kg) versus fish length (m). The plotted values fall into two general regions, one for fish with and one for fish without swim bladders. Each region is fitted by a straight line and provides an equation for target strength, when L is in metres.

With swim bladders:

$$TS/kg = -7.20 \log L - 36.80.$$

Without swim bladders:

$$TS/kg = 8.44 \log L - 48.54.$$

These equations have been used throughout to obtain the target strength values (Appendix Table 2) that are required to convert the acoustic back scattering measurements to biomass estimates.

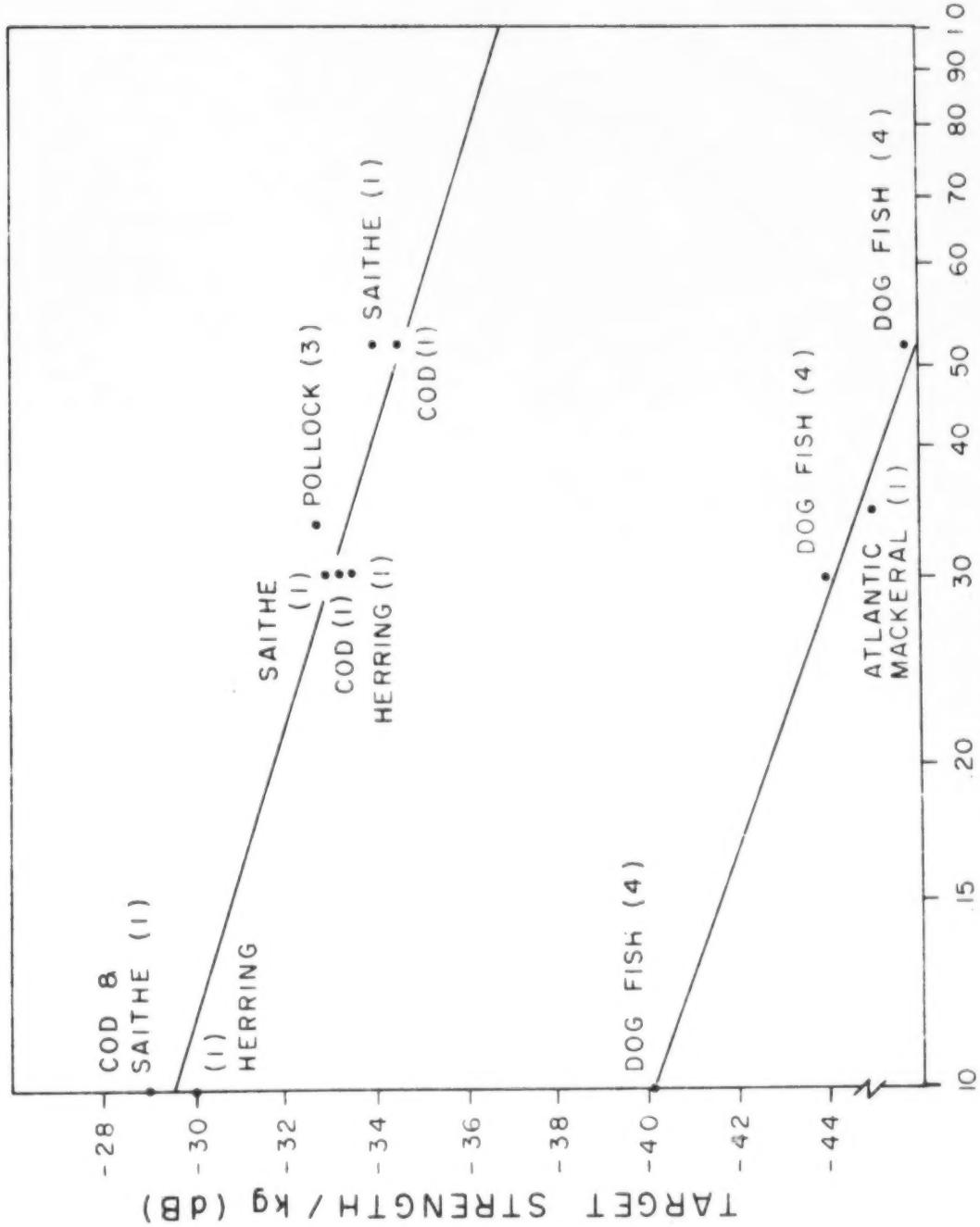
Appendix Table 1. Published target strength values and their source used in the derivations of target strength/kilogram values.

	Cod	Saithe	Herring	Atlantic mackerel	Cod	Walleye pollock	Dogfish
Reference	a	a	a	a	b	c	d & e
Length (m)							
.10	-29.0	-29.0	-30.0	-	-	-	-40.0
.30	-33.5	-33.0	-33.0	-	-33.25	-	-44.0
.34	-	-	-	-	-	-32.8	-
.35	-	-	-	-45.0	-	-	-
.50	-34.5	-34.0	-	-	-	-	-45.8

[a]Nakken and Olsen 1978.
[b]Edwards 1978.
[c]Traynor and Ehrenberg 1979.
[d]Forbes 1975.
[e]Jones and Geen 1977.

Appendix Table 2. Target strength/kg values used on cruises GBR80-7, GBR80-8, EH80-1, GBR81-3, and HB81-1, September, 1980, to March, 1981.

Species	Average length (m)	Target strength/kg (dB)	
		Calculated	Rounded
Herring	0.181	-31.45	-32.0
	0.234	-32.44	-32.0
Hake	0.547	-34.91	-35.0
Pollock	0.417	-34.06	-34.0
Rockfish - yellowtail	0.400	-33.93	-34.0
redstripe	0.293	-32.96	-33.0
canary	0.499	-34.62	-35.0
bocaccio	0.632	-35.36	-35.0
Dogfish	0.630	-46.8	-47.0
	0.740	-47.4	-47.0



Appendix Fig. 1. The relationship between fish length (m) and target strength per kilogram.